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Reviews the literature for the three-year period since the issuance of Volume XV, No. 4, October 1942. Earlier research related to this topic was reviewed in Volume XII, No. 4.

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INTRODUCTION

This issue of the Review covers research in the teaching of science and mathematics thru the interval from May 1945 to May 1948. The last two previous issues dealing with these subjects were the October numbers of 1942 and 1945 (Volume 12, number 4; Volume 15, number 4). In both of these issues the reviews were classified according to the grade level to which the research was related.

The committee responsible for this issue has favored grouping the summaries of research according to the purposes with which the investigators were concerned as they entered upon their work. The four main categories are (a) aims and purposes, (b) methods and materials, (c) measurement and evaluation, and (d) teacher education. Reviews appropriate to the category in each of the administrative divisions of the school have been brought together. This arrangement was made to help the reader recognize the common problems of investigators working with children at different levels of maturity. It will help the critical reader to discern the trends and to see in what particulars the different investigators are guided by theories derived from common, as well as from conflicting concepts of values. For example, the chapter on "Aims and Purposes of Science Teaching" makes it clear that some investigators—especially those working with younger children—recognize in the theory underlying their studies the values to be derived from (a) education for emotional development, (b) education for skill in the democratic processes, and (c) recognition of children's needs and interests as revealed thru studies of growth and development. Other investigators have been guided by theories of learning for understanding, by theories that favor differentiating young people on the basis of certain skills and abilities, and by theories derived from concepts of disciplinary or transfer values. The reader will be assisted in his criticisms of current theory and of technics and trends in research when these different and often conflicting efforts, directed toward the same general purposes, are brought together. This is, indeed, the main argument for bringing together reports of research in which elementary-school children are the subjects of study with research and reports in which young people of greater maturity are the subjects.

The collaborating authors of the first five chapters of this number were selected and assigned so that one would be primarily concerned with work with elementary-school children and one with work with students on a more mature level.

It will be recognized at once that any classification of the reviews must be more or less arbitrary and by no means discrete. This is evidenced in this issue by the fact that authors of chapters with different titles have, in a few instances, referred to the same studies. This duplication of titles in different bibliographies may seem objectionable but if these reviews are to be properly interpretative, some duplication can hardly be avoided.

There will be interest in contrasting the studies of aims and purposes in both science and mathematics that are reviewed in the chapters with this title with the studies reviewed in the chapter on measurement and evaluation. In the former there is clear effort to define aims and purposes with recognition of immediate usefulness and of continuity toward independence in learning and working. In the chapter on measurement the studies reviewed are concerned with measurement of factual learning, with problem-solving ability, with generalizing, and with applying principles, but mostly within the framework of teacher-controlled situations with neglect of evaluation of progress toward intellectual independence. Experimentation in education based upon educational theories derived from the philosophy of experimentalism has hardly yet been undertaken. Investigators in the area of measurement and evaluation will no doubt find suggestions for further fruitful research from closer examination and study of theory and practice in curriculum development.

The amount of research in the teaching of science and mathematics during the interval covered in this review seems larger, except possibly in the area of teacher education, than that of the previous three-year interval and comparable to the amount reported in an equal time interval before World War II. There seems to be reason to believe, however, that fewer of the research studies recently submitted to meet requirements for degrees are being published, and that fewer of the published studies would be regarded as particularly meritorious.

A large share of the responsibility for assigning and for assembling the summaries of research in teaching mathematics was assumed by William A. Brownell. In carrying forward this phase of the work, Dr. Brownell has in effect served as co-chairman.

SAMUEL R. POWERS, *Chairman*

CHAPTER I

Aims and Purposes of Science Teaching

N. ELDRED BINGHAM and JOE YOUNG WEST

RESEARCH workers examining the elementary-school science curriculum have found evidences of real concern for the emotional development of children, for democratic living, for the difficulty experienced in grasping science concepts, for the place of children's interests in building programs, and for the evaluation of the results of instruction.

Science in the Elementary School

In the attack of the Institute of School Experimentation (31) the "shortage areas" are of particular interest to science educators. There seems to be little uniformity in the results from the various interest studies. Blough (10) and his committee projected needed research in science teaching in the elementary school. The Science Committee of the National Society for the Study of Education in the Society's Forty-Sixth Yearbook, Part I (54) gives what is perhaps the clearest picture of the trends in science in the elementary school. In this yearbook the objectives of science teaching were defined, and a continuous integrated program of instruction in science was recommended.

Arisman (3) pointed out that education is a process by which changes are effected in people. He developed general criteria for meeting the emotional needs of children in the classroom. Workers in the field of elementary science should profit from the analyses of the concepts formulated.

Baker (4) analyzed third- to sixth-grade children's questions collected from a wide variety of localities in the United States. Since no categories were imposed, there was freedom for questioning. Fifty percent of the questions were in social studies, nearly 38 percent were in natural sciences and the remainder in various other fields. Surprisingly enough, barely 4 percent of the questions were related to the local community. Tho like in kind, questions by girls were more numerous than those by boys. Many interests seemed to run concurrently, and within a given area might be expected to continue for several years. The children were interested in origins and causes of natural and social phenomena. They wanted help in interpreting the facts and situations they observed. According to the investigator, in order to meet the needs of boys and girls, teachers need a rich background in the social studies, and in the biological and physical sciences, as well as information on current affairs.

Drill (19) in another study on children's interests in science, attempted to obtain reasons for interest in certain topics. On the basis of 47,330 contributions submitted by 10,453 children the following conclusions were reported: (a) Forty percent of all the contributions thruout the grades

indicated interest in science phenomena. (b) Thruout the grades boys showed greater interest in science than was shown by girls. (c) Children in this study were more interested in individual plants, animals, machines, or units of the physical environment than they were in societies of organisms in relation to their environment or in the stars, moon, sun, and the planets. (d) A slight advantage was shown in favor of biological sciences over the physical. (e) Kindergarten and seventh- and eighth-grade groups showed keenest interest in maintaining health, while the middle groups were more interested in intellectual pursuits. (f) Children occasionally showed some understanding of a scientific principle. (g) The season had some effect on the children's choice of topics, particularly of younger children.

Von Qualen and Kambly (70) investigated the science interests of fourth- to sixth-grade children from their choice of reading materials. They found a wide range of interests. Girls were least interested in plants, astronomy, earth's crust, magnetism, and electricity. Boys showed least interest in conservation, cloth, astronomy, weather, plants, light, and earth's crust. All pupils were most interested in ancient animals, science and industry, transportation, and living animals.

Paterson (57) used pictures in a study of the science interests of children in Grades IV to VI in three different environs within a city. His method of obtaining data on interests appears to be a promising one.

Hill (27) studied the appropriateness of objectives in science teaching proposed in the Forty-Sixth Yearbook of the National Society for the Study of Education Part I (54). Data were collected from Grades I thru VI by recording remarks verbatim and by recording responses into categories representing the accepted objectives. The following conclusions were stated: (a) The objectives listed in the Thirty-First Yearbook were appropriate goals in elementary-science instruction. (b) Children should be given more opportunity to engage in activities pertaining to responsibility, cooperation, initiative, and application of experience and skills. (c) The number of responses that children made did not increase from one level to another tho some recognizable differences were evident in the quality of the responses. The investigator urged educators to redefine objectives in terms of the relative excellence of response from children at various age levels.

In an examination of the explanations of scientific phenomena made by children, Oakes (55) found that the majority of their explanations were naturalistic, that children can learn correct explanations of many natural phenomena, that understanding of essential relationships increased with age among children, and that bright children are more likely to give physical explanations than the less bright. Oakes (56) also reported that where the correct concept is lacking, the explanations of adults did not differ materially from those of children.

Pella (58) analyzed the five most widely used textbook series in elementary science to determine the areas included, the topics discussed, and the concepts presented in each area without reference to grade levels. He reported that there was a fair degree of agreement in the five series as to the areas included. There was relatively little agreement among the topics discussed, and an extremely small amount of agreement among the concepts developed. There was a greater variation in the grade placement of the concepts than in the concepts presented, tho only 1464, or 16 percent, of the 8913 different concepts appeared anywhere in four or more of the series of five textbooks.

Science in the Junior High School

There have been considerably fewer studies made and less writing on the organization of courses of study in junior-high-school science than in other phases of the science program. There seems to be more confusion and lack of organization at this level than at any other. However, the following principles seem to have general acceptance: (a) science curriculums of junior high schools should be organized in harmony with elementary- and secondary-school programs; (b) the science program for the three-year junior high school should be organized into a unified sequence of experiences; (c) the material should be organized into large environmental units, and each unit should deal with worthwhile life problems, divided into significant subproblems which have significance for the pupils.

Glenn and his committee (25) proposed a number of important directions for research at this level. Among the questions proposed were the following: (a) What is a desirable sequence and time allotment for general science in the junior-high-school grades? (b) What elements of the scientific method and what attitudes can be taught so as to function in the lives of the junior-high-school pupils? (c) What are some principles basic to the effective use of multisensory aids in teaching junior-high-school science? (d) To what extent is pupil planning feasible in determining content and procedure for junior-high-school science courses? (e) To what extent do pupils evidence readiness for the more advanced science concepts? (f) Can the feverish, scattered pace of junior-high-school science be slowed down and be made more thoro? (g) Can a textbook be written which will avoid reducing the course to a review of elementary work, or a vocabulary-ridden sketch of high-school work?

Bissiri (8) investigated the present status of the natural science curriculums in junior high schools thruout the country and established criteria for evaluating them. He found the small amount of time given to science in many junior high schools and the lack of evaluation particularly alarming and concluded that present junior-high programs do not meet the needs of pupils. He proposed that curriculum committees should survey what is being done in other educational centers, then define their own criteria for organizing science offerings, and that subjectmatter should

be selected to meet present and potential needs of pupils, to meet different levels of ability, interest, and maturity.

Leonelli (43) determined the principles of physical and biological science found in eighth-grade general science textbooks. Case (13) determined the principles and experiments of physical and biological science found in ninth-grade general science textbooks. Whitman (72) made a study of the truthfulness of weather proverbs in terms of scientific principles. Hilty (28) investigated the lives and works of eminent men and women in several fields of science with particular regard to the part played by reflective thinking in their researches.

Smith (62, 63) tested the hypothesis that specific items of science information have a fixed difficulty for various populations, by selecting and teaching significant subjectmatter to groups of ninth-grade pupils. Appropriate tests were devised, standardized, and administered. Important findings were: (a) the difficulty of tested items varied as much as 50 percent when conditions and amount of exposure were varied; (b) the difficulty of the sampled items was too great for the average ninth-grade pupil to master with 50 percent success under the conditions of the experiment; (c) the most important factor in success in learning general science information was the selection of items of content; (d) variations in method and amount of exposure rank below the type of material and differences of ability; and (e) the abilities measured by mental tests and indicated by IQ are not necessarily the major abilities involved in learning general science material.

Science in the Senior High School

There is evidence of a continuing emphasis on defining and meeting student needs at the secondary level. This is found in both the authoritative reports and the researches. In the Forty-Sixth Yearbook, Part I of the National Society for the Study of Education (54) emphasis was placed upon problems of social significance which may be found in such broad areas of human experience as health, consumership, conservation, vocation, family relationships, and citizenship. Stratemeyer and others (65) stressed as the basis for a modern curriculum the characteristic life situations which are faced by learners. In the Eighth Yearbook of the John Dewey Society, Corey (17) directed attention to the developmental tasks of youth as the major goals of secondary education. These developmental tasks are outlined as (a) coming to terms with their own bodies, (b) learning new relationships to their age-mates, (c) achieving independence from parents, (d) achieving adult social and economic status, and (e) acquiring self-confidence and a system of values. With but minor exceptions, the researches show trends in keeping with the philosophy expressed in the above reports.

Robertson (60) studying the secondary schools of Ohio, found evidence that the widely employed subjectmatter approach has failed to accomplish the desired objectives of modern education. In most schools the concern

for the democratic way of living is low; teachers are operating according to outmoded psychological doctrines; adolescent needs, interests, and problems, as well as the community and its needs, are generally ignored.

Using a questionnaire previously developed by Hunter and others, Ahrens (1) and Hunter and Ahrens (32) summarized the objectives of science teaching in the secondary schools of California and revealed the shifts in these objectives which have occurred since 1940. An understanding of the environment holds first place in the junior high school, but the scientific method ranks first at the senior-high-school level. At both levels the scientific method, together with the attitudes and technics of the scientist increased in importance. While the functional group of objectives has decreased in importance, emphasis has been placed increasingly upon factual science material and upon preparation for college. This trend can be accounted for in part by the war. In spite of the fact that current educational literature stresses repeatedly the functional needs of youth as a basis for the curriculum, the evidence from this study shows that these needs are not being met. However, the pattern of science teaching follows more closely the newer concepts of child growth and development. Concepts and generalizations are developed by taking objective realities, using them as a problem, and then solving the problem. Ahrens concludes that science teaching must relate more closely than in the past to the material and social aspects of life.

The following studies show clearly that personal and social needs of pupils, rather than subjectmatter goals, should be stressed. Alpern (2) devised and administered tests to determine the degree of ability of a selected group of high-school pupils to test scientific hypotheses and to evaluate certain measurable factors related to this ability. Conclusions show that this ability to suggest procedures to test hypotheses depends in part upon the habit of delayed response, an element of the scientific attitude. He failed to find a significant correlation between the ability to select procedures to test hypotheses and chronological age, intelligence or reading grade. Keeslar (37) made an analysis of literature concerning the scientific method which could be used for instructional purposes in secondary schools. The list was checked by twenty-two research scientists. Current opinion to the contrary, the investigator found that the elements of scientific method are definite, distinct from scientific attitudes, and are known and used by scientists. He suggests that high-school teachers using this list might help pupils to find and solve everyday problems. Likewise in a survey of research studies dealing with the elements of scientific method as objectives of instruction in science, Keeslar (38) found that research workers often confuse scientific method with scientific attitude.

Weisman (71) reported that the development of understanding of scientific method at the secondary level is a legitimate objective. He attempted to determine experimentally whether or not the ability to interpret data can be improved by an experimental method in which the desired thinking out-

comes are set up as definite aims of instruction. Six biology classes were taught by the investigator using the experimental method, while six were taught by teachers considered equally good who thought that critical thinking would develop concomitantly as students followed the regular course of study. Results obtained after a year's instruction and again a year later demonstrated that the ability to interpret data can be significantly improved by the procedures used in her study. Rather than emphasis on memorization of facts and principles, the objectives of instruction become the recognition of assumptions, proper qualification of conclusions based on sampling, cautious use of predications, and care in drawing reasonable conclusions and in applying them to new situations. To realize the implications of the study would necessitate a thoro reorganization of the science curriculum around student interests and needs in the basic aspects of living and functioning in their own community. It further implies a change in both the curriculum and method of teacher education.

Since the ability to apply the principles of physics to practical out-of-school situations is one of the major objectives of instruction in high-school physics, Wise (73) investigated the relationship that exists between ability to recall information and to solve conventional problems, and the ability to apply principles in the solution of problematic situations typical of out-of-school experiences. He found that the abilities are not identical; both abilities are related to intelligence to about the same degree; and that grades are not a valid measure of either ability.

In a study of scientific inquiry in textbooks, Lampkin (40) revealed wide variability among carefully selected judges. Using multiple-factor design, twelve textbooks (three each from general science, biology, physics, and chemistry) were broken up physically and rearranged into twelve composite textbooks, each to be read by one of twelve readers, six with background in science teaching and six with background in philosophy. It was shown by analysis of variance technic, supplemented by two independent tests, that the readers varied not only on what aspect of scientific inquiry was referred to in certain statements, but also on whether any aspect was referred to. The following are some of the possible inferences from the data on reader variability: (a) The task of analyzing textual material for conceptual content is extremely difficult. Earlier studies of textbooks and related materials should be reviewed from this standpoint. (b) The readers projected their own ideas into what they read. (c) Where applicable, multiple-factor designs should replace single-factor designs in much educational research.

Evans (21) implemented the social needs approach by arraying the procedures one would use in the study of a community problem such as health.

By a survey of the literature, McKibben (51) investigated the relative values of the general objectives of biology for general education, together with the changes that have occurred in the last twenty years. Knowledge,

scientific method, health, economic, and general application objectives headed the list twenty years ago as today but now there is more emphasis than formerly upon the economic and social objectives. McKibben concluded that biology, to be of greatest value to the individual and to society, should emphasize the practical and the social to a greater extent.

Lurensky (45) investigated the applications of principles of biology in high-school biology textbooks. Eastman (20) attacked the problem of determining topics suitable for developing understandings of physical-science principles in a senior-high-school chemistry course, and Lovely (44) determined topics suitable for developing understandings of biological principles in senior high school.

Katz (36) studied the role of the textbook in developing a mastery of biology and in thinking. Analyzing specific texts according to certain criteria, he found certain texts superior with regard to the definition of words, while others presented problem material in a way that more effectively promoted scientific thinking.

Klise and Oliver (39) procured student reactions from their own biology classes. Certain units proved more popular than others, but the popular units were different for the two investigators. Among the results were student requests for more field trips and for more experiments or laboratory work.

Subarsky (66) experimenting with a group which possessed little racial prejudice, found that by providing for two integrations of biology and social studies during a term, one integration centering around physical and cultural development, and the other around human group relations, greater changes in racial attitudes were produced than by conventional courses in these subjects.

McGrath (50) investigated the relative significance and use of chemistry principles and generalizations in the general education programs of a selected group of high schools. Using the jury method to establish the relative significance of the principles and generalizations, he found a close agreement between the principles in use in the schools and those deemed significant, altho the jury of specialists would add principles and generalizations concerning the topics—sulfur, equations and problems, and the halogens. Those deemed of significance for general education include the portions of such topics as introduction to chemistry, atmosphere, oxygen and hydrogen, water, carbon and fuels, and chemistry and health that deal with practical everyday phenomena. Technical topics such as atomic structure, equations and problems, and the more difficult parts of metallurgy tend to be avoided.

In an investigation of the reasons for the election and nonelection of chemistry by high-school pupils, Murphy (53) found that boys and girls wish to learn more about occurrences in everyday life and the composition of the things they use daily. They also wish to work in a laboratory and to see demonstrations. He concluded that the course of study should

emphasize those aspects of chemistry that are related to the ordinary life of high-school pupils.

Two studies of physics textbooks were made, one by Perkins (59), who determined the extent to which the names of scientists are included in textbooks, the other by Benumof (6), who found that modern electrical communication is treated to a very slight extent in both high-school and college physics textbooks; that but two-fifths of the high-school physics teachers and but one-half of the college physics teachers mention or describe these modern developments, tho a larger proportion favor their inclusion. The modern developments include the Giorgi system of units, field theory, wave propagation, new generators, new resonators, crystals, wave guides, directional devices, microwave measurements, frequency modulation, facsimile transmission, automatic telephony, and television. Benumof proposed that the topics of electricity, light, and sound in elementary physics be enriched thru a descriptive treatment of recent advances in electrical communication.

Barnard (5) told of the desire of a committee of the National Association for Research in Science Teaching for research in secondary-school science to promote research in problem solving. Johnson (33) described the science-education research that is underway in the secondary division of the United States Office of Education.

The pre-war tendency toward a fused physical-science course is supported by the Committee on Science Teaching of the National Society for the Study of Education (54) and by the Cooperative Committee on Science Teaching of the American Association for the Advancement of Science (16).

By using a jury of specialists, Miles (52) determined the relative importance of the principles of physical science which are desirable for inclusion in an integrated course of physical science for the senior high school. He also determined the relative values of the experiments which are desirable for inclusion in such a course, and whether each of those experiments would more appropriately be done as a laboratory experiment or as a demonstration. Of the forty principles deemed essential by all the specialists, twenty-six were in physics (including astronomy and meteorology); eleven in chemistry; and three in geology. From the extensive list of experiments assigned to the forty principles, 125 were considered by all the specialists to be either ideally or well-suited for such purposes. Anyone responsible for the development of a physical-science course should read Miles' thesis.

Science for General Education at the College Level

McGrath (50) in an introductory editorial dedicated the new *Journal of General Education* to the goals of general education in colleges and universities. Among the salient features of the general education movement are (a) a reaction against specialism and vocationalism, (b) an effort to integrate the subjectmatter of related disciplines, (c) an attempt to assist

the student in seeing the relationship between learning and life and in using his skills in daily living, and (d) an attempt to reform graduate education for teachers. He advocated that our ideal of an educated man should be one educated for the life, labors, problems, and pleasures of our time.

In a report for the research committee on junior college science, Van Deventer (69) classified the general education science courses as of three types, survey courses, problems courses, and cultural heritage or historical courses. Of these types the survey course is by far the most widely known and best established. Interest in integrated science courses is on the increase in all types of institutions; most progress has been made in teachers colleges and least progress in junior colleges and Negro colleges.

Dodds and Lefler (18) reviewed the articles and researches that treat the influences of science and technology upon education in college. Rush (61) described a systematic process that he used in setting up objectives for a general course and then outlined means of implementing these objectives.

In an exhaustive study, Jordan (34) dealt with the problem of how, in a university, a student majoring in a field other than science is to secure a liberal education in science, and as a corollary, how the science major can acquire a grasp of concepts embodied in branches other than his own. He examined the aim of liberal education together with its relationship to democratic living, the general and specific shortcomings of Liberal Arts science programs for general education, laboratory study, and certain specific aspects of the curriculum. He concluded that use, or the needs of the student, should be the principal criterion to use in choosing material for science courses in general education. He suggested the development of comprehensive, rather than survey courses, according to these principles: (a) The course should be built around a nucleus of basic principles of various phases of science with principal facts that are needed to build these principles. (b) The content should be completed with a discussion of common phenomena. (c) The content should be arranged in a sequence to illustrate the manner in which concepts have developed historically. (This does not pertain to choice of content, but merely to arrangement; the student's present environment is the controlling factor in choice of content.) (d) Reference should be made to the interaction between scientific development and social change. Using the above principles Jordan built a curriculum for a one-year course in physical science.

On the basis of the opinion of fifty students who had completed survey courses, Blanchet (9) attempted to determine the relative desirability of different topics for inclusion in survey courses in biology and physical science. However, the lack of agreement was so great that he concluded such opinions are of little value in selecting course content.

Van Deventer (68) described the studies and procedures used in developing the general biology course at Stephens College. To orient the

course toward present and future needs, an analysis was made of science materials in representative periodicals and student selections of activities. Eight subjectmatter areas were selected—animals and plants, food, body form and function, man's activities, man's uses of materials, and science and man's thinking. Student problems, classifiable as personal and behavior problems, family problems, community and social problems, and intellectual and esthetic problems were used in determining what to teach in the eight areas. Out of this a program of instruction, consisting of projects and group experiences, chosen on the basis of individual interests and needs, was developed. Not only does the course contain all the facts and principles ordinarily found in a standard biology course, but also much additional material.

Primarily by analysis and jury technics, Bergman (7) procured and matched with biological principles a list of fifty principles of entomology. By similar technics he determined the significance of these principles to twenty-five criteria of general education. In this study the principles were listed in serial order according to their significance for general education.

Friedenberg (23) compared the development of an experimental group of freshmen agriculture students taking chemistry from a needs approach with that of other freshmen studying chemistry from the traditional subjectmatter approach. He found the experimental group demonstrably superior in their ability to apply chemistry to all but one of the needs areas considered in the course, and there was no evidence of inferiority in regard to that single area. There was evidence of the experimental group's inferiority, however, on a published examination measuring the traditional objectives of chemistry, and on the control group's own examinations. It seems pretty clear that the objectives one strives to attain have much to do with the outcomes of instruction.

Health and Nutrition Education

General concern is expressed among research workers over the status of health education in the schools of the nation. This concern is perhaps an outgrowth of the war, which revealed startlingly poor conditions among young men being examined for military service. Researchers in recent years have attacked the problem from various viewpoints: administrative, basic philosophy, pupils' ideas of the importance of content, and attitudes toward health.

Part I of the Forty-Sixth Yearbook of the National Society for the Study of Education (54) revealed the trends in health education. The committee preparing this book recommended that health education be integrated with the entire school curriculum with one exception, that in the eighth year a one-semester separate course in health and physiology be presented. The findings of the following studies are in general in harmony with the committee's recommendations. Carmody's study (14) attacked the health-education problem from the standpoint of the administrator in de-

veloping a program framework in which curriculum offerings, pupil-teacher ratio, time-space facilities, and relationships with cooperating community agencies were considered. The investigator wisely avoided recommending specific subjectmatter and programs of activities, and suggested that syllabus revisions, to be developed by the various committees concerned, should be flexible and suggestive rather than prescriptive.

A unique and thoro study, which may be taken as a model for the development of health programs, was conducted by Tyler (67) serving as Health Education Consultant on loan from the U. S. Public Health Service. The objectives were to help the people of a given area develop a total health-education program which would give each individual an opportunity to participate, and to stimulate the development of health programs for larger areas. Careful surveys, previously made, provided the basis for planning, and each activity listed was carried out on a countywide, and in most cases, on a statewide basis. The investigator concluded that by working together a community can build up a health program which otherwise would be impossible; that the democratic method, altho slow, is sound and worthwhile; and that the methods and technics employed in this study are effective and would be useful in other areas. This splendid on-the-spot study must be read to be properly appreciated.

Maltby (48) studied the possible future importance and placement of nutrition education in Grades I thru XII of the public-school systems in the United States. Questionnaires were mailed to persons judged as experts in the field of nutrition. Upon the basis of 486 replies the following conclusions were drawn: (a) Human nutrition is sufficiently well established scientifically to justify its teaching in the public schools. (b) Nutrition education should be required for both boys and girls. (c) Current school-lunch programs do not provide sufficient nutrition education. The investigator found that public opinion is highly in favor of nutrition education as a separate subject in public schools, but that the chief obstacles are lack of recognition of need for such education, and lack of trained personnel.

Lockwood (41), working on the study under way at the Harvard School of Public Health, stated that the purpose of this research is to improve technics of nutrition education and to determine whether or not nutrition education, when incorporated into the curriculum, will aid in influencing and changing the food habits of children. To date the findings are at the elementary level, but data will be available later for the other levels. The schools receiving the most help showed statistical evidence of improvement in the children's daily eating habits. There was a favorable change of attitudes of children in relation to their food habits which persisted a year after the nutrition instruction. To get the best results, nutrition education should be carried on in a continuous and progressive manner.

By means of 1100 questionnaires, 450 personal interviews and an analysis of 500 voluntary class reports, Haar (26) determined the learners'

preferences for particular units of health subjectmatter, and their interest in specific ailments. The interests revealed by the three methods correlated highly, with the exception that sex education ranked second as revealed in the personal interviews, but did not appear in either the questionnaires or in the oral reports. Also those personal interviews given to servicemen revealed an interest in marital relationships not evident among the high-school students.

In an effort to have the content and methods of instruction chosen because of their significance to human living, Manwell (47) developed health-teaching materials, and then determined the extent to which high-school teachers influenced the behavior of students by the use of these instructional materials. From the results of tests administered before and after the instructional interval the experimental group showed significant gains in information and slight gains in the other proposed areas. The investigator stated that the technic used in the development of the suggestions for teaching is suitable for application in other areas of instruction where there is a close relationship between problems of the individual or of social and modern scientific knowledge. Readers may wish to question the length of the instructional interval which was five weeks.

Lockwood's study (41) proved timely in that an outbreak of infantile paralysis occurred almost immediately afterward. The study was planned to help high-school pupils overcome fears of this disease arising from rumor and widespread misinformation. Pupil reaction and comments at the conclusion of the study and the reaction of parents showed that accurate information can help build a more wholesome attitude toward disease as well as increased respect for research studies related to health and disease.

Consumer Education

With regard to consumer education, Mallinson (46), by careful research procedures, selected and assigned seventy-three categories of consumer-education knowledges to principles and/or attitudes or general science courses. Thirteen of the knowledges were assigned to principles of physical science, forty-five to principles of biological science, and fifteen to scientific attitudes.

Describing the activities of the Consumer Education Study, Briggs (11) pointed out the need among educators for a wider concept of consumer education. Skill in judging commodities needs to be supplemented by an understanding of the general principles of our economy, of the machinery of production and distribution, and of wise procedures in planning for a full, rich life of cooperation with one's fellows. He also reported two criteria formulated by representatives of business and of education for judging the quality of commercially prepared materials offered to schools free or at nominal cost, namely, (a) all material offered by business to schools shall contribute directly to the enrichment of the educational program, and shall contain no sales promotion whatsoever, and (b) the name

of the donor shall appear, both because a proper credit is due him and because it will enable a reader to take into consideration any bias that may be included.

Preparation for Future Needs

On the basis of need as determined by job analyses of the chemical industries in the environs of Nashville and thruout the state, Holladay (30) developed a vocational-chemical education program for Nashville and projected programs for other centers thruout Tennessee.

Two studies were concerned with vocational agriculture. By an analysis of various reports and by personal visits to farm homes, Freeman (22) conducted an extensive study of the needs of Negro farm families located in southeast Missouri and then projected a program of education at Lincoln University for them and for other Negroes thruout the state. Using job analysis technics, Karls (35) constructed courses of study in agriculture for the elementary and secondary schools of southwest Missouri and for the Southwest State Teachers College at Springfield. He found great need for extending and improving agricultural education in the area studied. Only 40 percent of the teachers attending college had studied agriculture. In the construction of the courses of study, emphasis was placed on the poorest farm practice of southwest Missouri.

Preparation for Further Studies

The studies that have to do with preparation for advanced work are more concerned with easing the transition from high school to college, or with what background is favorable to success in a subject, than the propaedeutic objective itself. Investigating the effect of the study of high-school chemistry upon success in college chemistry at the University of Redlands, Hoff (29) found that the study of chemistry in high school had no significant beneficial effect on the grades achieved in college; also that a student has approximately a 50 percent chance of receiving the same grade in college chemistry that he received in high-school chemistry.

Garrett (24) reported on the method used to avoid repetition at Ohio State of work mastered in high school. From 5 to 15 percent of all beginning chemistry students who have had high-school chemistry pass proficiency tests which place them in second-quarter work and for which they receive five quarter hours credit. The distribution of the second-quarter grades reveals that most of the students receiving such credits surpass the remainder of the chemistry students.

Believing the physical-science course of the Summit High School of New Jersey to be more functional than the more traditional chemistry and physics courses taught there, Carleton (12) inquired of selected colleges and universities, including all of those to which Summit High School graduates go, to find if physical science is acceptable as a college entrance credit. Of the seventy-eight institutions that replied, all seventy-eight will

grant credit for the physical-science course. His analysis of the replies should be useful in establishing respectability for such a course.

Using the rigid pre-professional training standards of the medical profession when investigating southern junior-college offerings in biology and chemistry, Chapman (15) found among other things that (a) for the most part, the junior colleges are making suitable offerings in both biology and chemistry, and (b) terminal and survey courses may be quite acceptable to general education, but should not be offered by the student to a medical college for transfer credit.

Investigating essential chemical backgrounds, Wiser (74) found that home-economics students need one year of inorganic chemistry, two quarters of general organic chemistry, and a third quarter of special organic chemistry devoted either to the chemistry of foods and physiological processes, or to the chemistry of textiles, depending upon the area of concentration.

Conclusions

Thruout the research summarized here there is evidence of a concern to use science to bring about a new and better culture, rather than merely to continue the past emphasis on implanting an old one. There is an increasing tendency to plan curriculum experiences that foster the proper emotional development of the child. The objectives expressed in the Report of the Science Committee of the National Society for the Study of Education in the Society's Forty-Sixth Yearbook, Part I, have been shown to be worthy ones for elementary-school children. Much of the subjectmatter formerly taught in the junior high school has now rightfully found a place in the elementary classrooms. The place of science in the junior high school is not clearly shown. In many instances it is merely a review of elementary work. Increasing emphasis is being placed on the scientific method as an aim at this level.

Tho the emphasis in the better schools at the senior-high-school level is upon the personal and social aspects of science, especially the use of the scientific method in solving problems and in making decisions, there are many reports of investigations that show but little concern for adolescent needs, interests, and problems, and in which there is little recognition of the connection between the school and the community.

The movement to provide an adequate orientation in science for all college students is gaining momentum, especially in teachers colleges and certain private ones. There is need for much improvement in this regard however, especially in the junior colleges, the Negro colleges, and the large universities.

The trend is away from highly specialized courses in the secondary school. Yet there seems to be a place for pre-vocational training based on job analyses in specific localities. The school is called upon increasingly to develop better citizens, fitted to earn a living or to pursue further studies.

The transition from high school to college can be made more efficiently by better articulating the two programs.

Much research is needed to improve instruction in science at all levels. It is gratifying to find that so many of the studies in science education during the past three years are of such high quality, but it is disconcerting to find that so much of this high quality research has not been published.

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CHAPTER II

Aims and Purposes in the Teaching of Mathematics

HAROLD E. MOSER, LUCIEN KINNEY, and CHARLES PURDY

THE research related to the aims and purposes in the teaching of mathematics in both the elementary and the secondary schools is reviewed in this chapter. Part I deals with the research on objectives and aims in arithmetic in the elementary-school grades and in the mathematics commonly taught in the junior high school. Part II summarizes the research on objectives in high-school and college mathematics.*

I. Elementary-School and Junior-High-School Mathematics

The period 1945 to 1948 provided only a few published studies relating to the aims and purposes of teaching mathematics in the elementary and junior high schools. On the other hand, a number of articles of theoretical interest appeared which are certain to influence research in the immediate future. In view of this intimate relationship between actual research and its conceptual frame of reference, no apologies need be offered for the summaries of theoretical points of view here included.

Social Utility Arithmetic

Aims and purposes. The position of the advocates of social utility arithmetic has been summarized by Wilson (43, 44). According to this view arithmetic should equip the child for life by becoming a part of his life. This it does by providing "a valuable tool applicable to the affairs of daily living," and by providing a field of interest and enjoyment thru recreation. Mathematical phases of arithmetic content are often developed thru an appreciation approach. Frequency of appearance in social usage determines whether the classroom approach should be drill or appreciation. Skills, knowledge, and appreciations are to be emphasized in proportion to their usefulness in adult life. Schools are expected to provide direct experience in social situations (usually sizable thought-provoking situations) and from these the learner acquires both number concepts and social meanings.

Current Trends. Research to implement this approach has appeared at intervals since 1918. Much of the research consists of surveys of business, industrial, and personal needs for number concepts in the adult world. Other research reports the success of children in mastering the reduced drill load. Present trends in the social usage theory according to Wilson

* Harold E. Moser of State Teachers College, Towson, Maryland, was mainly responsible for the material presented in Part I. Lucien Kinney of Stanford University, with the assistance of Charles Purdy of San Jose State Teachers College, prepared the material in Part II.

are: (a) reduced drill load to be learned to 100 percent mastery; (b) abandonment of isolated textbook problems; (c) further progress in developing the recreational and appreciation approach in mathematics.

New Research. Several studies were offered in the period covered by this review which fit into this frame of reference. Russell (35) studied the use of decimals in the occupational world. He surveyed eighty-nine industries employing 68,000 persons. His report covers both the need for reading decimals and the limits of decimal computation.

Morton (27) studied children's interest in questions relating to aviation in Grades I-VIII as clues to grade placement of phases of this topic. He found that children were interested in the sociological aspects of aviation, especially in relation to speed, time, money, and measurement. He concluded that textbooks ought to be revised to supply more factual information and thus help children to gain number meanings thru experience. Lyda (25) studied the relationship between practical social experience and success in problem solving. He concluded that practical experience is a potent factor in success in solving problems—more potent for children below average in intelligence than for those of average intelligence or better.

Dexter (9) analyzed a recent arithmetic textbook series to compare the problem work with old texts and to see how well the needs of the social-utility program were being met. She found that 27 percent of the problems were purely artificial and that less than 1 percent of the problems were real to children.

Criticism of Social-Utility Theory. The theory underlying social arithmetic has been attacked by a number of writers. Wheat (41) has raised the following conceptual objections: (a) It does not follow that because the adult with his knowledge of number can see number meanings in specific social situations, the untrained child can experience the social situation and derive the number meanings as an outcome. (b) To split up and spread out the topics of arithmetic on the basis of frequency in adult usage is to ignore the principles of relationship and continuity within the topics. (c) A survey of the computational needs of adults is an inadequate basis for determining the mathematical content in the curriculum because the number responses of adults are so intimately intertwined with personal and social situations that he rarely dissociates one from another.

Other writers have joined in opposition. Brownell (3) criticized the social survey on the grounds that results obtained represented minimal standards for selecting content and was geared to a low level of competence. It would be better, he argued, to survey understandings and skills that are desirable. Johnson (20) criticized the research of Russell (35) on the basis that a survey of adult uses at a given time does not reveal processes that would have been used with better training. No improvement in methods or content can be looked for if the impetus must come

from usage followed by inadequately trained adults or an earlier generation.

Meaning Arithmetic

Aims and Purposes. The case for the meaning theory of mathematical instruction was presented by Brownell (4), Wheat (40, 41), and others. Meaning arithmetic demands that arithmetic be intelligible, sensible, and useful to the learner rather than mechanical. The primary purpose of all mathematical instruction is to help children attain growth in the ability to think quantitatively. The ability to think thru a quantitative situation and arrive at sound conclusions with respect to it depends upon: (a) an understanding of the nature of the number system and especially of the principles and relationships which serve to make it an instrument for quantitative thinking; (b) a command of number symbolism—the language of mathematics; (c) a command of the fundamental processes; (d) the ability to correlate grouping arrangements described for specific social situations with the principles of mathematical grouping studied earlier.

Very little new research relating to the aims and purposes of meaning arithmetic was reported during the period 1945-1948. The research pattern needed to satisfy the exigencies of the meaning theory is vastly more complex than research based upon the drill theory. Brownell (3) has provided research workers with a survey of problems in need of investigation and has outlined needed changes in technical procedures to produce better studies of learning. Whiteaker (42) warned that no real assessment can be made of the values of meaningful instruction until the whole curriculum field is reorganized with a view to finding a topical continuity better designed to emphasize important number relationships. A number of curriculum problems were outlined.

Criticism of Meaning Theory. In the Second Report of the Commission on Post-War Plans (30) most of the program sponsored as meaning theory has been endorsed by the committee. On the other hand, Wilson (43) attacked the meaning approach as "disciplinarian," and "an attempt to stretch the mental powers of the child to the limit." Wheat (40, 41) criticized the tendency of some educators to take the middle-of-the-road stand with respect to meaning mathematics by setting up both social aims and mathematical aims.

Instructional Aims in Relation to the Growth and Development of Children

Three studies tracing the growth of number concepts in young children were reported. Mott (28) used the interview technic to show that of the forty-four children tested (age range thirty-four to seventy-three months) 92 percent had developed concepts for the numbers from one to ten. The

quality of the performance of children with eight-months attendance in nursery school and kindergarten was superior to that of those without school experience. In a second study Mott and Martin (29) interviewed sixty-six first-grade children, who previously had been tested at the end of the kindergarten year, to see whether first graders retained the number concepts learned in kindergarten. Only in rote counting in the higher decades did the children show loss after a lapse of three months in number training. The writers attributed the retention to the fact that young children need and are using numbers in their home environment.

Stotlar (36) studied the number concepts of nineteen children (ages fifty to sixty-nine months) one year before beginning formal instruction. She found no marked difference between skill in rote counting and in forming number concepts and concluded that both advanced at about the same rate. The studies reported in this section tend to confirm the growing conviction that readiness for learning number ideas and skills is primarily the product of relevant experience and not merely the effect of becoming older.

Davis and Rood (8) sought to find the extent to which pupils retain certain basic computational skills while studying the increasingly complex materials of the upper grades. The progress of fifty-six pupils entering Grade VII was studied over a two-year period by means of a series of five tests. The writers concluded that one cannot assume that an ability once demonstrated will remain at the same height of efficiency even during a short period of four months. Recovery of abilities is easier immediately after loss than at later periods.

II. Secondary and College Mathematics

Kinney (22) set up certain criteria by which objectives may be appraised both for purposes of selecting activities and content and for purposes of evaluation of outcomes of instruction in high school and college mathematics. Kilbridge (21) utilized an interesting procedure to obtain a statistical check on the classification of the objectives for the comprehensive examination in Mathematics 1 at the University of Chicago. He also experimented with a method for checking the discreteness of the objectives of the course. The objectives implied in the test items were compared with the objectives set up by the authors. The two sets of objectives thus obtained were found to be about the same. Correlations between problem responses in the areas of various objectives revealed that ability to solve elementary problems correlated .78 with ability to use fundamental ideas of space, number, and logic in algebra; that ability to do deductive reasoning in logic correlated .40 with the same ability in geometry; and that two successive levels of difficulty in ability to use fundamental ideas of space, number, and logic correlated .36.

Attempts to define desirable outcomes for mathematics have continued along two major lines:

1. Surveys of mathematics required for adult usage—nonvocational, vocational, and college. Few of these studies have investigated the level of proficiency required for personal efficiency.
2. Studies of deficiencies existing among high-school and college students, with some attention to causal factors and remedial procedures.

Prevey (33) studied the relationship between childhood experiences with money and later use of money, and, also, between responsibility which children are allowed to assume in the use of money and their general level of adjustment during high-school years. Some relationship was found in both cases. Thorndike (38) found that grades in general mathematics are more predictive of grades in physics than are geometry grades. In a study of students entering a state university without credit in high-school mathematics Benz (2) found that about half were on probation at some time and only about one-fourth eventually graduated.

Russell (35) studied decimal usage in the occupational world, surveying 68,000 persons in eighty-nine industries. The majority of the employees had no need for percents. Seventy percent of the census classifications reported that less than one-tenth of their populations used decimals. Sutton (37) reported a questionnaire study in which responses were obtained from sixty-nine secondary and college administrators and teachers after they had participated for one summer in the Chrysler Corporation work program. This program consisted of work in the factory and a series of conferences. Responses to the questionnaire indicated that while the average worker uses little science or mathematics, advancement frequently depends upon both.

Research for this period further verified the mathematical deficiencies previously described in pupils at all high-school levels, as well as the college-freshman level, and in certain specific college courses. Rausch (34) found that retention of a computational skill by teachers was directly related to the use they made of it in their field of specialization. Ebert (10), investigating the ability of eighth-grade pupils to achieve mathematical generalizations, found significant relation between generalization and mental ability and between generalization and reading ability. Guiler (12, 13, 14) found that a large percent of the ninth-grade students were incompetent to deal with percent and to handle decimals and common fractions. Ohlson (32), in studying achievement of students in Grades X, XI, and XII, of forty-three Iowa high schools, found that the present program is equipping less than 50 percent of the students with needed mathematics in a wide range of detailed areas.

Guiler (15, 16, 17) studied the deficiencies of college freshmen in common fractions, decimal fractions, and percents and found no important

differences between the deficiencies of college students and the deficiencies of a ninth-grade group in high school. Analysis of the nature of errors revealed a need to institute a remedial program in higher educational institutions. Kinzer and Fawcett (23) similarly found important arithmetic weaknesses in beginning chemistry students as measured by a placement test. Eshbach (11), Nielsen (31), Hayes (18), and others pointed out the inadequacy of preparation in mathematics by college engineering students, and they also emphasized the need of greater articulation between mathematics and engineering.

Burton (5) described the beneficial effects of a remedial program in high school. Kinzer and Fawcett (23) reported the improvement in arithmetic by college chemistry students as indicated by a retest following three weeks of remedial instruction. In a follow-up of these same students Kinzer and Kinzer (24) reported a correlation of .52 between the retest grades and college chemistry grades.

In study of causes of deficiencies in mathematics among high-school and college students a variety of factors have been investigated. A committee of the Association of Mathematics Chairmen of New York City (1) found fifteen factors significantly associated with failure including personal habits, out-of-school activities, and lack of interest. Holzinger and Swineford (19) investigated the predictive value of the spatial and general deductive factors of a test given to eleventh-grade geometry students at the beginning of the year. The test included eight spatial tests and three additional tests of ability to separate the spatial factor from the general factor. The scores on all eleven factor tests had a correlation of .768 with the geometry achievement test given at the end of the year. Torrance (39) found a relationship between performance on selected items considered important for mathematicians from the *Strong Vocational Interest Blank* and the mathematical achievement of those in the top 10 percent of interest and those in the bottom 10 percent of interest. Only three of the top fifty had ever failed mathematics, and only four of the bottom fifty had escaped failures in mathematics. Cattell (7) made a study of the relationship between mathematical abilities and personality data taken from carefully controlled ratings on thirty-five personality trait clusters "known to be representative of the whole personality sphere." The subjects were 123 adult males in the Army Student Training Program. When the effect of intelligence and of ability on the *Graduate Record Examination* was partialled out, the correlations of mathematical ability with individual personality traits were practically zero.

A general overview of the research in the area of mathematical deficiencies in high school and college lends weight to Buswell's (6) suggestion that there is need for greater emphasis on research relating to procedures for correcting and preventing computational difficulties as compared to that directed to discovering and defining deficiencies.

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CHAPTER III

Methods and Materials in the Teaching of Science*

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THERE is an increasing amount of evidence indicating that the program in the teaching of science is a cooperative activity in which the teacher and students work together in determining objectives and methods, in pursuing investigations, and in drawing conclusions and evaluating outcomes.

Current Practices in Science Teaching

According to the 1947 Yearbook of the National Society for the Study of Education Part I (22), progress toward greater cooperative activity in the classroom has been particularly evident in junior-high-school science and in biology. These teaching practices have not been used so effectively in high-school chemistry and physics. Teaching practices in general have not been successful in developing ability to use the scientific method as an outcome of science education. A more encouraging report was made by Leonard (16) who studied the practices used in the high schools of thirteen school systems and found evidence of schools utilizing direct approaches to learning in science, with well-equipped laboratories operating in functional ways. He also found schools making use of effective methods of research and investigation, with specific attention to competence in expression and the communication of ideas.

The use of direct experience in the elementary school was the thesis of the bulletin, *Science Education for the Elementary Schools of Ohio* (27). According to this bulletin direct experiences may be used in promoting effective learning thru cooperative group activity. The status of science in the elementary school was one concern of the committee reporting to the President in the publication entitled *Manpower for Research* (28). In this report the President's Research Board utilized the report of the Cooperative Committee on the Teaching of Science and Mathematics which had been authorized by the American Association for the Advancement of Science. Altho the committee recognized the deficiencies commonly present in the teaching of science in the elementary schools, the committee found encouraging developments in the preparation of curriculum materials and teaching aids. Some specific indications of the encouraging trend in elementary-science teaching are as follows: (a) the increased allotment of time to science; (b) an increase in the number of science classrooms equipped with laboratory equipment for providing science experiences; (c) the provision of more and better visual materials and supplementary reference materials; (d) the increase in the number of well-written textbooks; and (e) curriculum provisions for problem-solving activities.

* The first five sections of this chapter were originally written by John S. Richardson.

Several studies have been conducted which are indicative of the emphasis that is currently being placed upon the desirability of cooperatively developed learning activities in science based upon the needs and interests of the learner. Bissari (5) conducted a study to determine the status of junior-high-school science and to determine the means by which it could be improved. The sources of the investigator's basic data included previous investigations, opinions of authoritative writers, courses of study, interviews with school principals and questionnaires submitted by science teachers. One hundred and sixteen schools in forty-five states were represented in the study. Based upon the findings of this study a number of generalizations were developed to serve as guides in the improvement of junior-high-school science instruction. Certain of the generalizations stated that science teaching should be organized around large units of experience based upon the pupils' needs and interests.

An investigation in a high-school physics class conducted by Hellman (13) included the planning of laboratory studies of the pupil's own choice. Hellman reported that results in pupil understanding and learning by this procedure were superior to those achieved by the traditional methods. A somewhat similar study was made by Lockwood (18), who designed a project to combat needless fear and panic among children and parents caused by the occurrence of poliomyelitis in a community. The study included approximately one hundred students of the tenth-grade biology classes in a Detroit school. The students participated in planning a study which included an investigation of fears, and popular questions regarding the disease. Numerous sources of information which had bearing on these and other phases of the general problem were utilized. It was reported that the project resulted in: (a) the replacement of fear by wholesome attitudes, (b) the replacement of hearsay by fact, (c) acquisition of information concerning symptoms of the disease, and (d) an increased appreciation of the need for research in all studies of health and disease.

Selection of Learning Materials

With the growth of science as a part of the elementary-school curriculum, the selection of learning materials appropriate to the objectives and methods has become increasingly important. A major criterion for the choice of materials, as set forth in the Forty-Sixth Yearbook of the National Society for the Study of Education Part I (22) is that the materials should come largely from the child's environment. The same point of view is expressed in the bulletin, *Science Education for the Elementary Schools of Ohio* (23). These documents emphasized the use of materials that are familiar to the pupil, the advantages of using materials that can be obtained thru local sources, and the construction of simple equipment as a desirable form of learning. It was also pointed out that the supply of motion pictures, slide films, and other visual and auditory materials is inadequate at the elementary-school level.

Audio-Visual Aids

An extensive survey conducted under the sponsorship of seven publishing companies (7), revealed among other things, a number of pertinent facts regarding the use of teaching films in 424 of the 501 largest public-school systems in the country. For this part of the study information was obtained thru questionnaires introduced and distributed to school personnel by salesmen of the sponsoring publishers, and thru interviews with visual-education directors conducted by a staff of well-trained research workers. In both the elementary and secondary schools, films were found to be used most frequently in science and social-studies classes. It was evident that the teachers included in this study were having difficulty in making effective use of teaching films. These teachers reported a variety of criticisms regarding the films which they had found unsatisfactory. These included criticisms pertaining to the appropriateness of the film, its subjectmatter and content, quality of the script, quality of production, obsolescence, and advertising. Science teachers were found to make unfavorable comments more often than the other high-school teachers. Subjectmatter and content of films were most frequently the subjects of their criticism.

Miles and Spain (20) reviewed the use of audio-visual aids in the armed services. On the basis of a considerable quantity of cited research and studies of opinions, the following conclusions were formulated regarding the educational value of audio-visual aids: (a) Films can and do affect emotional attitudes in predetermined desirable directions, and they increase factual knowledge and promote the length of its retention. Filmstrips are valuable, but are not so successfully used as motion-picture films. (b) The preparation of the student for seeing a film increases the learning value of films, and audience participation in the use of filmstrips increases the amount of factual knowledge gained. This increase was especially significant with difficult material, with groups of low motivation, and with groups of average and low intelligence. (c) The research studies on the effectiveness of special audio-visual devices permits no general conclusions. (d) All studies of the opinions of the instructors and trainees indicate a general approval of the extensive use of audio-visual teaching aids.

Keeslar (14) attempted to determine the extent to which selected instructional films in science contributed, particularly by means of the unique and special functions of the medium, to the realization of three major objectives of secondary-school science. The three objectives with which this study was concerned were: (a) to effect an understanding of everyday scientific principles, (b) to teach the elements of scientific method, and (c) to develop the scientific attitude. In carrying out this study twenty-four films rated as "excellent" in two outstanding film catalogs were selected. These films were analyzed on the basis of evaluative criteria. The evaluative criteria were designed to determine if the films served unique functions of films in teaching, if they served specialized functions, or if

they contributed to the three major objectives of science teaching. A special check-sheet was devised and a record was kept as to whether or not each individual scene in each film contributed to the above objectives. The reliability of the investigator's judgment was checked by a second analysis of three of the films six weeks after the first analysis, and agreement in 90 percent of the cases was found. The validity of the investigator's judgment was checked by having most of the three films analyzed by three experienced science teachers with an agreement of 86 percent, while a check of the investigator's second analysis with that of the three judges showed a 95 percent agreement.

On the basis of the evidence found in this sampling of the best films for use in high-school science classes it was shown that unique functions of films were served by 48 percent of the films, that specialized functions of films were served by 8 percent of the scenes and that only 5 percent of the scenes were found to contribute to any of the three selected objectives of science teaching. Therefore, nearly half or 44 percent of the twenty-four films served no unique or specialized function and contributed to none of the three so-called major objectives.

Commercial Materials, Devices, Pictures, and Books

The abundance of supplementary learning materials which are available to science teachers from commercial sources has made the problem of selection a difficult one. In an effort to help science teachers, a committee of the National Science Teachers Association, in cooperation with the Consumer Education Study of the National Association of Secondary-School Principals (21) undertook an investigation of the problem. As a result of this investigation certain uses which could be made of commercial materials and factors limiting their uses were identified. Commercial materials were found to be useful in: (a) supplementing the information available in textbooks, (b) providing accurate sensory experience, (c) maintaining a stimulating atmosphere in the science classroom, (d) providing experience in the application of scientific principles, (e) providing current materials on new developments in science, (f) aiding in the analysis of objects and processes, (g) stimulating student interest in science, (h) developing the special interests of individual students. Factors which limited the use of commercial materials were: (a) the presence of an objectionable amount of advertising or sales promotion material; (b) the variety of sizes and shapes made the material difficult to store, catalog, exhibit, or use; (c) content which was not appropriate or which was not presented in a way conducive to learning; (d) the presentation of information which was inaccurate, half-true, or distorted; and (e) nonavailability of material when requested. It was proposed that commercial materials should be used only when it was certain that they made a positive contribution to the educational program and contained no objectionable advertising.

Stollberg (29) investigated the possibilities of providing and using teaching devices in the study of electronics. He designed and produced vertically placed panels upon which plaques bearing pieces of electronic equipment and schematic diagrams of these pieces of equipment could be placed and studied while in use. The design of the equipment for demonstration use and for individual laboratory study, along with the explanations of its functions and uses, and suggestions for teaching constitute a significant contribution to this developing aspect of science in life activities.

Goins (11) analyzed ninety-seven pictures from *Life* and *Fortune* to determine their appropriateness for use in science classes. Most of the pictures were found to be valuable teaching aids in two or more science courses.

As the result of a review of 145 high-school chemistry texts published between 1802 and 1944, Rice (25) found that the number of illustrations in chemistry texts had increased and that more applied science was included in current chemistry texts.

Storage of Materials

Provision for adequate storage of learning materials is a problem that apparently has been given little attention by the investigators. The importance of this problem was recognized in the report prepared by the National Science Teachers Association for the Consumer Education Study of the National Association of Secondary-School Principals (21). A method of solving one aspect of the problem was developed by Richardson (26), thru a study of the functional storage of pamphlets and charts. Greene (12) investigated the storage of laboratory equipment and supplies. On the basis of recommendations and requirements of state departments of education, the recommendations of textbooks and laboratory manuals, of equipment lists of manufacturers of science apparatus for high-school use, and of questionnaires sent to teachers of high-school chemistry, Greene developed master lists of equipment and supplies for chemistry, physics, biology, and general science. The requisite storage area was calculated from these lists. Recommendations for drawer, shelf, and cupboard space were made. Formulas for the use of these recommendations by schools having single laboratories for chemistry and physics, for general science and biology, and for schools having a single general laboratory, were developed.

Effective Ways of Using Learning Materials

An eighteen-month study of the use of current materials in classes was made in eleven cities and towns in California under the direction of the California State Department of Education (6). Sixteen schools and thirty-six teachers participated in the study. Of the seventy-two classes, twenty-two were in science. Materials used included current magazines of pictorial-

news types, current educational films and recordings, pamphlets produced by industrial and commercial organizations, and many films and filmstrips. The study began with a workshop for teachers to clarify purposes, study procedures, and methods of evaluation. Representatives of the State Department of Education and Stanford University made regular visitations to the schools included in the study. Conferences for teachers were conducted on several occasions during the period of the study. Emphasis upon the use of current materials in the classroom was brought about thru a variety of procedures including panel discussions, individual reports, field trips, use of bulletin board, displays, and recordings. The achievement of classes in which current materials were used was compared to the achievement of control classes conducted according to standard practices. Students using current materials made as good scores on tests covering the standard curriculum as did students in the control classes. The greater resourcefulness required to use current materials resulted in better interest and participation and more critical thinking. The varied approaches provided for individual differences among students. Students developed respect for each other and a sense of individual responsibility. Attitudes favorable to and habits in the use of current materials were developed. Teachers were reported to have benefited from the study by developing skills in locating and using current materials and by learning to plan with the students. Better relationships with the home and community were believed to have been achieved thru the study.

Lockwood (19) reported a study designed to determine whether nutrition education in the elementary school would aid in changing the food habits of children. Six elementary schools in Newton, Massachusetts participated in the study during the school year 1946-47. The intelligence of pupils in the different schools was as comparable as is possible in dealing with entire school populations. Two of the six schools were used as controls, and the teachers in these schools were not encouraged to emphasize nutrition education any more than they had been accustomed to doing. In two other schools the teachers were supplied with pamphlets, posters, charts, films, and other teaching aids pertaining to nutrition at the elementary level. Teachers in the remaining two schools were given teaching-aid kits plus workshops, demonstrations, and personal conferences. These materials and teacher activities were planned to give teacher assistance in incorporating nutrition education in the different activities of the elementary school. Before the study began and at two different times during the year, dietary surveys were taken of each of the 3300 children included in the study. Comparisons of the relative effectiveness of the different approaches to nutrition education were based upon the findings of these surveys.

In the two schools where teachers were given assistance thru workshops, demonstrations, personal conferences, and visual aids, children were reported as showing statistical evidence of improvement in their daily eating

habits. There was also evidence to indicate that the attitudes of children toward new foods improved during periods of definite and continued emphasis upon nutrition education. There was a rapid decline in interest in daily food adequacies of the basic food needs during periods when nutrition education was not emphasized.

Methods of Using Motion Pictures

Wise, Miller, and Wahl (36) reported a series of two studies designed, among other things, to determine the relative effectiveness of various methods of using selected sound motion pictures in general science classes upon subjectmatter learned. In the first study, a film entitled "Electrodynamics" was shown to 180 pupils enrolled in eight general science classes after the completion of the unit on electricity and magnetism. In four of the classes the film was introduced with a carefully planned discussion and followed by a discussion of its content. These discussions were presented by the investigator. In the other four classes the film was shown without preliminary or summary discussions. Objective type tests, covering the subjectmatter included in the film, were administered before the film was shown, one week after, and again seven weeks after the showing of the film. Classes in which planned discussions were used to introduce and follow up the showing of the film made significantly greater gains in both immediate and delayed recall of subjectmatter than classes in which no discussion was used.

In the second study an attempt was made to determine whether gains similar to those obtained in the first study might be expected for different sound films and whether similar gains might be made by having the regular classroom teachers prepare and present the discussions used with the films. Two eighth-grade classes in general science were shown two sound films, "Heat and Fuels" and "Weather" approximately one week after related units were studied by the classes. The first film was shown to one eighth-grade class after a thirty-minute discussion period directed by their regular teacher and based upon a learning guide developed for the particular film. The same film was shown to the other eighth-grade class with no preliminary discussion. The method of presenting the second film to each of the eighth-grade classes was reversed so that each class saw one of the films by each of the methods of presentation. Two ninth-grade general science classes were shown two sound films, "Water Power" and "Simple Machines" following a procedure similar to that used with the eighth-grade classes. An objective-type test was used for measuring the recall of subjectmatter covered in each of the four films. The test for each film was given before the film was shown, one week after, and again seven weeks after the showing of the film. Groups were equated for purposes of comparing results obtained by each of the two methods. With the exception of gains on the test on "Water Power," the gains made by pupils observing the

films after preliminary discussions were significantly greater than the gains made by pupils observing the films without discussions.

An investigation of the effectiveness of note-taking while viewing motion pictures in high-school science classes was made by Ford (10). Thirty students of ninth-grade science were shown three sound films by each of three procedures. With the first film there was neither preparation nor preconditioning. With the second film the students were told to take notes during the showing for reference later in preparation for a test. With the third the students were given reading references two days before. Prior to showing the film appropriate models were demonstrated and discussed. This was followed by listing the things which they should look for in the film. The students were directed not to take notes and were told that a test would be given immediately after the showing. On the basis of the tests given in each case the investigator concluded that note-taking during the showing of a film distracted from the learning principles whereas adequate preparation of the student for observing a film encouraged greater learning and promoted good conduct.

Nature of Learnings in Science

An understanding of the nature of specific learnings, their relationship to each other and factors affecting their achievement is essential in planning and administering effective learning activities in science.

In a study involving 600 boys and girls, Alpern (2) found that high-school pupils possessed ability to test scientific hypotheses as measured by evaluative instruments by the investigator. Low correlations were found between intelligence, chronological age, and previous science taken by pupils and their ability to test hypotheses. No statistically significant differences were found between the ability of the pupils in testing hypotheses.

Wise (35) conducted a study to determine the relationship between the abilities involved in recalling information, solving conventional problems in physics, and applying principles of physics to problems encountered in out-of-school experiences. Objective-type tests designed to measure these abilities were administered to physics classes in seven high schools at the completion of each of the four conventional units in physics. It was found that the abilities to recall information and solve conventional problems in physics were not identical to the abilities involved in applying principles of physics in solving problems encountered in out-of-school experiences.

As the result of a study involving twelve classes in high-school biology, Weisman (34) found that the teaching method used, general intelligence of the pupil, reading ability, the amount of mathematics the pupil had previously taken, partiality for science, and skill in critical thinking, had a relationship to the pupil's ability to interpret data in biological science. Within the age range of pupils included in the study, the ability involved in the interpretation of data was not found related to sex or age. The

extent to which method of teaching was found to be a factor in developing the ability to interpret data is reviewed in a later portion of this chapter.

Special Course Organization and Teaching Technics

A number of investigators have been concerned about the effectiveness of various kinds of course and unit organizations upon the achievement of certain outcomes in science. Others have attempted to develop teaching technics which would be effective in achieving specific outcomes.

Subarsky (30) compared the relative effectiveness of an experimental procedure and the conventional procedure for administering high-school biology and social-studies classes upon the achievement of biologically and historically valid concepts and desirable attitudes regarding discriminatory social practices. By the conventional procedure pupils were taught biology and social studies in separate classes. By the experimental procedure the biology and social-studies classes were brought together at two different times for a two-week period given over to integrating what the pupils had been studying concerning the physical and cultural aspects of human development and group relations. As measured by the tests used in this study there was a significant positive change in the attitudes of pupils studying by the experimental procedure. There was no significant change in the attitudes of pupils studying by the conventional procedure. The findings of this study suggest one way in which more effective learning might be achieved in an area of human relations important in democratic living. This study also indicates a way in which resourceful and energetic science and social-studies teachers could plan more functional educational experiences even within the course pattern and organization found in the conventional high school.

Reports of several studies present some evidence regarding more effective organizations of learning activities and more effective teaching technics, altho they were not based upon the findings of controlled experimentation. Adams (1) devised laboratory demonstrations which would be useful in developing an understanding of the thirty generalizations of physical science which were found to be most functional in the activities carried on in industrial arts shops. Kotlar (15) described a course for twelfth-grade pupils on the interaction of science and society and reported that the results of tests indicated that pupils were apparently getting the important generalizations of the course. Lewis (17) described a procedure which was found effective in preparing laboratory exercises in junior-college science designed to develop abilities in using the scientific method. Robinson (27) attempted to develop a fused science course for Grades XI and XII which would help the individual become a more effective participant in a democracy.

The nature of these reports might be interpreted to mean that science educators are becoming increasingly concerned with the development of

course organizations and teaching technics which will help persons taking science achieve outcomes of greater personal and social significance.

Bases for Comparing Methods

A number of investigators have attempted to compare the relative effectiveness of different methods of teaching science. Various learning outcomes were used as bases for determining the relative effectiveness of the methods investigated in the studies reviewed here. It is interesting to note the importance that has been placed upon attitudes, abilities in problem-solving and the application of the subjectmatter of science to practical situations. Altho outcomes related to scientific attitudes and abilities in problem-solving are defensible bases for comparing the effectiveness of different methods of teaching science, there is still a great need for valid and reliable instruments to measure many of the elements involved in these outcomes.

Enrichment and Problem-Solving Methods

Baar (3) conducted a critical analysis of selected literature dealing with methods of teaching science and synthesized three enrichment methods. An enrichment method was considered to be a teaching procedure which seemed to modify the quality of pupils' school life in a meaningful way. One method, an activity method, involved the use of differentiated enrichment activities. The second, a problem method, made use of the scientific method. The third, a social implications method, emphasized the social implication of science.

In the second part of this study an attempt was made to compare the relative effectiveness of each of the three methods and combinations of the three methods in teaching general science based upon growth in the ability to determine cause and effect relationships; understanding the social implications of science; comprehension and interpretation of scientific problems, experiments and achievements; and application of principles and reasoning in the application of principles. The achievement of groups of general science pupils in six classes taught by the experimental methods was compared to the achievement of general science pupils in an equated group taught by a conventional method involving textbook, recitation, and lecture demonstration. Achievement was measured by objective tests administered before and at the end of the period of instruction. In general, the enrichment methods were found to realize better achievement in the outcomes with which this study was concerned, altho the differences in favor of the enrichment methods were not statistically significant in all cases.

Bloom (4) investigated the effects of instruction in problem-solving upon the improvement of abilities in problem-solving and upon general achievement of a selected group of college students. Interview tests were given selected students to determine the procedures they used in arriving at conclusions to specific problems included in examinations covering the fields

of social science, humanities, and biological science. Difficulties encountered by students of various achievement levels were compared. The poorer students had difficulty in understanding the problem, had less confidence in their ability to solve problems, and tended to drift aimlessly thru the problem. Students in general were found to possess the essential information needed to solve the problems. Remedial work in problem-solving, where the technics used by better students were studied, realized greater improvement in the problem-solving abilities of students when compared to equated groups of students who had not been given the remedial work. Students who had been given remedial work in problem-solving also made better grades on examinations covering general learning outcomes than students in the control groups. The reliabilities of the differences obtained were not reported.

Laboratory Methods

Cunningham (8) analyzed thirty-seven studies dealing with the problem of lecture demonstration *versus* individual laboratory methods in teaching science. These studies included six doctoral theses, eighteen master's theses, and thirteen articles. It was found that the data did not conclusively favor one method over the other. The desirability of one method over the other was determined by the objectives sought and the conditions under which the course was taught.

Tobler (31) found that high-school biology pupils, who were required to label prepared drawings, made better scores on examinations selected to measure factual learning and functional values of the products of learning than equated groups of pupils who were required to prepare and label all drawings.

Weisbruch (33) found a "semimicro" method of conducting laboratory work in high-school chemistry to be superior to the "macro" method based upon achievement in laboratory procedures and knowledge of the subject-matter of chemistry.

Effects of Method upon Ability to Interpret Data

Weisman (34) compared the relative effectiveness of two methods of teaching high-school biology upon achievement in the ability to interpret data in biological science. Six experimental classes and six control classes in tenth-grade biology from the same high school participated in this study for a period of nine months. The experimental classes were taught by a method which provided for teacher-pupil cooperation in selecting the problems and planning the activities for the biology course. Emphasis in the experimental classes was placed upon solving problems selected by pupils. The control classes were taught by equally good teachers using their customary methods within the conventional organization of the biology course. Mental ability, ability to do critical thinking, knowledge of biology, reading ability, and ability to interpret data, as measured by tests

administered before the period of instruction, were used as bases for equating the groups.

It was found that pupils in the experimental groups achieved reliably greater gains in the ability to interpret data as measured by the *Interpretation of Data Test*, than did pupils in the control groups. Pupils in the experimental groups also made significantly greater gains in learning facts and principles of biology as measured by the *Cooperative Biology Test*. One year after the period of instruction pupils in the experimental groups had retained their superiority over pupils in the control groups in the ability to interpret data and in knowledge of biological facts and principles.

The findings of this study correspond to the findings of related studies which have previously been conducted in that it was found possible to achieve certain of the abilities involved in problem-solving as outcomes of science instruction. Furthermore, technics of teaching involving the cooperative participation of pupils were found to be more effective than teacher-dominated methods in achieving these outcomes.

Student Opinions in Evaluating Methods of Teaching

The opinions of students have been used in some studies as one means of evaluating teaching procedures at high-school and college levels. Two such studies will be reviewed here. By using a questionnaire, Doll (9) obtained the preferences of 1237 pupils in six New Jersey and Pennsylvania high schools for teaching procedures which he classified as *laissez-faire*, low-level democratic, high-level democratic, and totalitarian. Respondents to the questionnaire identified many weaknesses in traditional teaching methods. They desired guidance in learning but not domination by the teacher.

Park (24) obtained opinions from fifty-four high-school pupils and ninety-three college students regarding the effectiveness of motivating technics which had been used by their teachers. He found that competition, rewards, and prizes were frequently used by teachers and were judged to be successful motivating technics by about one-third of the students. Audio-visual aids were mentioned by 18 percent of those responding whereas 19 percent of the group considered the teacher's personality and knowledge of subject to be important factors in motivating learning. No attempt was made to distinguish between the motivating technics used by teachers of various courses.

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CHAPTER IV

Methods and Materials in the Teaching of Mathematics

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The summaries of research relating to methods and materials in the teaching of mathematics are presented in two sections in this chapter. Part I deals primarily with the problems of teaching arithmetic in Grades I to VI. Part II is concerned with the methods and materials related to the teaching of mathematics in the secondary-school and college levels.*

I. Mathematics in Grades I thru VI

Since the preceding report in this series (11), a large proportion of the writing on methods and materials has been concerned with general methods, the grade placement of topics, and the nature and place of meaning in teaching arithmetic. Once more it is true that only a few of the articles and studies reviewed here consist of reports of controlled research on the problems of teaching arithmetic.

The nature and place of meaning in the teaching of arithmetic was dealt with by Brownell (6, 7, 8, 10). He distinguished between meaning *of* and meaning *for* in the case of arithmetic and suggested four categories under which the meanings of arithmetic might be grouped (6). Pointing out a general confusion resulting in the teaching of social applications of arithmetic rather than the meanings and rational principles which make arithmetic a phase of mathematics, Brownell listed objections to teaching meanings, followed by reasons for teaching them (10). He explained and illustrated his concept of meaning (7, 10), and listed results of experimental situations which favored his meaningful method of teaching borrowing to third-grade pupils, over mechanical methods taught to another like group (10). Implications for research in arithmetic were outlined (8) as problems under two headings: (a) making arithmetic sensible, and (b) making arithmetic useful. Technical procedures needing change are those involving control, measurement of progress, length of observation, and the base of evaluation. A word of caution concerning superficial meaning was offered in an article by Whitney (71).

Stevens (63) in reviewing trends in teaching listed five procedures of note: (a) There has been a marked increase in the time and attention given to concept-building programs. (b) Abstract work has been delayed. (c) Methods of today recognize and accept immature ways of dealing with number situations. (d) There has been a decided increase in, or a return

* Herbert F. Spitzer of the State University of Iowa is responsible for the preparation of the material presented in Part I and for the references dealing with the teaching of arithmetic. Part II was prepared by Robert L. Burch of Boston University.

to, oral work. (e) The emphasis today is on individual in place of mass instruction.

Six principles embodying a usable philosophy are listed by Cooke (11): (a) Introduce concepts and problems of arithmetic only when the child is psychologically prepared for them. (b) Practice and drill on those topics that need practice and drill. (c) Recognize and provide for individual differences among pupils thru diagnostic and remedial procedures. (d) Approach problem-solving logically. (e) Use word problems with a vocabulary one grade below the arithmetical level. (f) Socialize and configure word-problem material.

In a critical analysis of the backgrounds of arithmetic, Renfrow (55) pointed out the impossibility of substituting algebra for arithmetic, the importance of the concrete approach in arithmetic, the need for mastery rather than omission of number processes, and the necessity for drill.

Gavian (23) listed and analyzed a number of problems that might be used to develop socio-economic understanding. As a part of the analysis, questions that six- to seven-year-old, eight- to ten-year-old, and ten- to twelve-year-old children might ask were listed. An example is, "How may boys and girls add to the income of the family by other means than earning money?" Larrick (41) observed that more children are handling a larger share of the family income. Children in families where both parents work are doing the grocery shopping and need lessons in money management.

Fawcett and Barcus (21) presented a report in which conservation situations are used as the basis for mathematical study exercises. The procedure offers what appears to be an excellent way to study some problems of conservation and if generally adopted should result in good uses of mathematics.

Orienting his thinking along the line of use and efficiency, Hill (31) urged a high degree of uniformity in (a) understanding of the objectives and philosophy functional to the teaching of arithmetic, (b) philosophy of textbooks used, and (c) procedures taught to children. He concluded that the place for teachers to show initiative is in the formulation and use of devices which make the work understandable to children. Essentially the same plea was made by Steel (62).

In an article, "The Social Utility Theory as Applied to Arithmetic," Wilson (74) reviewed the long struggle between the followers of mental discipline and the followers of use. The most significant studies on use of numbers were cited or quoted, and the type of program previously proposed by Wilson was recommended. Two separate studies, one by Mott (51) and one by Stotlar (64), on the number abilities of four- and five-year-old children were reported. In general the findings of these two studies were similar to earlier and more extensive studies in this area. In both studies the conclusion was reached that four- and five-year-old children do use and have need for numbers, and therefore might profit from instruction. Because some children counted a larger number of blocks than the highest

number reached on the rote counting test, Mott reached the somewhat dubious conclusion that rote counting plays no part in learning to enumerate objects. Altho no evidence in support of the statement was submitted, Mott stated that rote counting was a handicap.

Mott and Martin (50) reported that with the exception of counting by rote to 100, children carry over into the first grade after a lapse of three months the number experiences they have learned in kindergarten. The results of the test showed this general tendency in every ability except rote counting to 100, a fact which raises the question as to whether the number concepts tested were learned in school or out of school.

In a comprehensive summary of a series of studies Osburn (52) presented an analysis of difficulties in long division. For one type of division, that of a two-digit divisor and a one-digit quotient, the number of possible examples for each of forty-one levels of difficulty was presented. The 49,050 possible cases for this one type of division were classified according to whether or not the apparent and the increase-by-one method of finding the quotient can be used successfully. (The figures Osburn quoted vary slightly from those reported in an earlier study by Grossnickle. For example, the latter reported that in 63 percent of all cases the apparent method succeeded, while Osburn reported 61 percent.) Osburn recommended that only the apparent method be taught to beginners.

In another report on the relative accuracy of estimates of the quotient when the increase-by-one and the apparent methods were used with two-figure divisors, Morton (48) recommended the increase-by-one method for two place divisors ending in 6, 7, 8, 9. His data showed that by following this rule estimates will be correct in 79 percent of the cases, while with the apparent method correct estimates will be obtained in only 36 percent of the cases for divisors ending in 6, 7, 8, and 9. Morton states that this use of the increase-by-one rule with divisors ending in 6, 7, 8, and 9 combined with the use of the apparent method with divisors ending in 1, 2, 3, 4, and 5 is in harmony with the practice of rounding numbers in other situations. The fact should be noted, however, that in general practice a number ending in 5 is more frequently increased in rounding than decreased, as Morton suggests.

Karstens (37) described a study which showed that it is possible, by using only the first two figures of any multifigured divisor, to select the correct quotient in almost 100 percent of the cases without doing any writing. This method consists of rounding off the divisor to the first figure and obtaining an approximate divisor. The estimated quotient should then be checked by multiplying the first two figures of the divisor by the estimated quotient before writing the product. If the check product can be subtracted from the first three figures of the dividend, it is safe to assume a high degree of accuracy for the estimated quotient.

After analyzing the ability to recognize relationships in problems, Spangler (60) suggested the use of oral problems and listed fourteen

procedures for improving pupils' ability to read problems. She reported further that improvement in problem-solving on the *Stanford Achievement Test* accompanied improvement in reading.

Also implying that teachers should provide practice at verbal levels is Hall (27), who gave a test consisting of fifty one-, two-, and three-step problems covering addition, subtraction, multiplication, and division of whole numbers to 179 unselected sixth-grade pupils. He found considerable individual differences but no significant differences between the ability of boys and girls. The order of difficulty of steps was as follows: addition (53 percent correct), subtraction (52 percent correct), division (49 percent correct), multiplication (42 percent correct). The order of difficulty of steps was as follows: one-step (66 percent correct), two-step (47 percent correct), three-step (32 percent correct).

Maintaining that reliance upon a formal system robs pupils of self confidence in whatever problem-solving ability they had, and in effect makes them slaves to the system, Beatly (1) withholds approval of all systems, (such as "step analysis") for problem-solving. He prefers that the teacher shall "supply a sufficient number of genuine problems which the pupil has a good chance of solving successfully by his own thinking" together with enough problems that stretch the pupil's power in order to whet interest. Payne (53), in an article entitled "Arithmetic Troubles," used the findings of research studies in a way that should be of vital concern to all research workers. She pointed out that research has shown that over one-half of the children in fifth grade are not ready for the study of fractions, and therefore schools are in error for not postponing the teaching of fractions. While Payne is not misquoting any research study, it should also be recognized that other studies have shown that fifth-grade children are mentally able to begin the study of fractions.

Johnson (33) referred to research from which he concluded that addition and subtraction of fractions as parts of units should be limited to the oral manipulation of halves, fourths, and eighths. More complex manipulations would be eliminated, and their counterparts taught decimally. Decimals would then be taught earlier as a continuation of whole numbers and the United States money would be taught with emphasis on the concept of place value thruout. He recommended that time thus saved be used in teaching the relations of numbers and their ratios and factors, as expressed in their common fraction form. In another article (34) Johnson explained the use of ratio blocks in helping pupils gain the concept of a fraction as the relation of two whole numbers.

Solutions to problems in teaching arithmetic based upon the findings of the Chicago committee in 1938 were reported by Johnson (35). He cited experimental evidence which indicated that decimal fractions are easier to learn than common fractions, and pointed to the need for further experiments directed toward answering the question, "Can mathematical concepts be taught?"

Christofferson (15) suggested the use of problems to illustrate division by a fraction, and to provide suitable material as a springboard for plunging into the study of this phase of arithmetic. He included explanations of seven settings for giving meaning or common sense to the process. Those explanations listed under the headings, "Multiplying Dividend and Divisor by the Same Number," "Using a Common Denominator," "Series," and "Laboratory Experimentation—Using Actual Measures" seemed useful.

Points of view on the question of when to begin formal arithmetic instruction and drill were presented by Sauer (57) and Falk (2). The former advocated basing the arithmetic program on planned number experiences, with formal drill beginning in Grade III, at which time records of growth might be maintained on graphs. Grades IV, V, and VI would work with more difficult experiences, and the atmosphere of the arithmetic class would be similar to that of the social-studies class. Falk reported that as a result of the institution of an informal arithmetic program in kindergarten and Grade I and the beginning of formal instruction in Grade II rather than III, the children in San Diego schools were a year above the national norms. For the new program new workbooks and supplementary aids are provided.

Poritz (54) and Van Engen (68) discussed the strengths and weaknesses of teaching addition and subtraction by use of triads. Van Engen attacked the use of triads as mechanical and without meaning. Poritz replied that recognition of the relation of one number to the others in the triad is meaningful.

The teaching of place value in the first grade was recommended by Morton (47). This assumes, of course, that provision is made for counting, reading, and writing numbers as part of the curriculum of that grade. He favored Brueckner's method of teaching the meaning of the first number in relation to the second as in 11, by the use of the first-grade pocket or wall chart. Work with the chart in the primary grades provides experience which is a helpful basis for column addition and building multiplication facts. By using two pocket charts in the intermediate and upper grades the relationship between whole numbers and decimals may be shown.

A plan for presenting percent was advocated by Van Engen (66) who would greatly increase the amount of time spent on establishing ideas, terminology, and symbolism before attempting work on the cases. He suggested work on terminology (5 percent is 5 per hundred) for the development of a rate idea. In Grade VI, percent is presented as a ratio, gradually leading to the idea of hundredths. (He likened the three cases in percent to the formula for finding area of a rectangle ($A=bh$) wherein any one member may be determined when the other two are known.)

In another article Van Engen (67) urged the advantage of the caret method of placing the decimal point in quotients on three grounds: (a) the relatedness of decimal and common fractions, (b) its value in establishing

a background for ratio, and (c) the necessity of the principle itself for the understanding of common fractions.

A method of self-instruction for learning the thirty-six addition combinations with sums from 11 to 18 and their corresponding subtraction facts in Grade II was described by Wilburn (72). His method involved regrouping (as changing 9 + to 10 + 8). The same author described (73) procedures which were successfully employed to assist 291 third-grade pupils in twelve schools to learn to use a ten in subtracting. "Using a ten in subtraction may be defined as the rearranging of a group of tens and ones so that a larger group of ones than exists in the original group can be removed."

In an extensive and carefully controlled experiment Brownell (9) secured data relative to the decomposition and equal addition methods of teaching subtraction; both were methods taught mechanically and rationally. The results warranted these conclusions: (a) if the decomposition method is to be taught, it should be taught rationally; (b) if the equal addition method is to be taught, either mechanical or rational procedures may be used; (c) equal additions taught rationally produced superior results on immediate- and transfer-rate tests, but decomposition taught rationally produced superiority on immediate and delayed accuracy and transfer accuracy tests; (d) unless methods of teaching are considered in experimental studies, no statement can be made regarding relative efficiency of working procedures. This last conclusion is very significant and should be considered when findings of earlier studies on decomposition and equal additions are reviewed.

Suggested devices, activities, and discussions of method, as exemplified by references (26) (32) and (70), were found in nearly every issue of *Grade Teacher* and *Instructor*.

Just seven articles pertaining to teaching are reviewed, two of which are bibliographies. Buswell (13) in his annual reports of selected references, listed fifty-eight titles in the field of arithmetic. In the other bibliography reviewed, Butler (14) presented annotations on fifty-one titles dealing with the improvement of reading in mathematics. Many of the articles and suggestions should be of value to the teachers of elementary-school arithmetic.

Lists of equipment and concrete illustrative and self-discovery materials deemed useful in the classroom were prepared by McSwain (45) and Sands (56) who also discussed the arithmetic program.

Dexter (20) classified the written problems in the four books of one series. More than a third of the problems were called possible but improbable while a fourth of the problems dealt with purely artificial situations. Less than 1 percent of the problems dealt with real situations as defined by Dexter.

Grossnickle (25) reported a study of the illustrations in each of the five books of eight different series of children's textbooks. All illustrations

were classified as decorative, associative, and functional. The last class was subdivided into static and dynamic. The number of illustrations varied from an average of one for every 2.3 pages to one for every 5.6 pages. The most popular-sized illustration in every series occupied from 20 to 40 percent of a page. The percent of total pictures of the decorative type ranged from 8 percent to 1 percent of the total illustrations; associative illustrations varied from a high of 74 percent in one series to a low of 42 percent in another. Percents for the static functional ranged from 12 to 7 percent, and for the dynamic functional, from 46 to 11 percent.

II. Secondary-School and College Mathematics

In the areas of secondary-school and college mathematics, the articles reported in the literature were predominantly concerned with observations and experiences, and only a few descriptions of planned research were available.

After analyzing more than fifty college textbooks in general mathematics, Brown (5) concluded that the content varied from the traditional courses in algebra, trigonometry, and analytic geometry to selected topics in higher mathematics, and its applied fields. Brueckner (12) re-emphasized that we must consider the social phase in mathematics, and gave a selected annotated bibliography of materials and methods to help in the achievement of this goal.

After observing the mathematical difficulties of 7000 students in a Naval Training School, Gowan (24) noted that these students were low in ability to (a) recognize when an answer is unreasonable, (b) determine degrees of accuracy, and (c) accept the absolute necessity of having accurate answers.

Miller (46) outlined a course in arithmetic for the twelfth year and reported that it had proved to be just as worthwhile as any other high-school mathematics course.

An article by Kinney and Freeman (39) was concerned primarily with certain psychological principles, but the implications for methods and for organization of materials were also discussed. These authors pointed out that: (a) learning is a purposeful and active process and that mathematical principles and processes should be studied first in situations in which they have been or will be used; (b) learning is a reorganization of behavior and in the organization of learning experiences should develop out of the current status of individuals and should be planned on a long-time cyclical basis with arithmetic experiences extending beyond the eighth grade; (c) learning is by wholes, and that the planning should include an overview period, an assimilative period dealing with detailed aspects, and a summary period to bring the parts into relation again; and (d) learning is colored by feeling and emotion and that pupils should recognize the significance of what they are doing, should be given evidence of

progress toward the goals, and should engage in activities related to their needs of the moment. Implications were discussed in connection with the organization of activities, the planning of repetitive learning, and the designing of a program of evaluation.

In its second report, the Commission on Post-War Plans (17) included among its theses several which were concerned with basic principles to be used in devising methods and in selecting materials. Pertinent suggestions were made concerning materials which should be included in the program for teacher training. Theses regarding multisensory aids were also developed. In another report (16), this same commission presented important guidance information for high-school students who are interested in the field of mathematics as a career. A bibliography was included.

In an investigation concerned with arithmetic problem-solving, Lyda (19) gave a set of thirty verbal problems to pupils in Grades VII thru XI. He then had five pupils from each of these grades work orally the three problems that had been missed by 96 to 100 percent of all the pupils tested. Numerous weaknesses were found in the various arithmetic abilities. These findings led Lyda to conclude that high-school students: (a) should be tested periodically with respect to the fundamental arithmetic operations; (b) should be given remedial teaching based on the test results; (c) should be retested; and (d) should be taught arithmetic and other problem-solving procedures in every subject, thus making every teacher an arithmetic teacher.

Albers (1) selected sixty-four pupils with Stanford Binet intelligence quotients of 125 or higher, and formed two groups of thirty-two each equated according to intelligence quotients, initial algebra achievement as determined by Form S, *Cooperative Algebra Test*, and chronological ages. She used one of these groups as an experimental group and one as a control group to study the advisability of providing enrichment material for superior students. An enrichment inventory test and an interest questionnaire were administered to both groups. Each pupil of the experimental group was given a booklet with the enrichment content and permitted to work on it during the extra time in the regular class period and also at home. At the close of the experiment, both groups were given another form of the algebra achievement test, the enrichment inventory test was repeated, and another interest questionnaire was administered. The results revealed that tho the experimental pupils had averaged about 15 percent less time on the regular algebra work, they made the same amount of improvement on the algebra achievement test as the control pupils. On the first enrichment test, the experimental group had a mean of 5.92 and the control group had a mean of 6.06; on the final enrichment test, the means were 20.28 and 7.88, respectively. For the total interest scores, the increase in mathematics-science interest was not statistically significant for the control group (critical ratio .68), but there was a statistically significant increase for the experimental group (critical ratio

3.72). Because the enrichment material was planned for self-administration and self-testing, it took very little of the teachers' time.

Recognizing that more emphasis must be placed on coordinating the work of elementary and secondary mathematics, Kinsella (40) selected ten basic relationships which are stressed in the meaningful teaching of arithmetic and translated these from arithmetic to algebraic context.

Stabler (61) recommended that a logically developed unit should be included in the course in algebra so that, among other things, pupils may have a brief introduction to postulate systems, may be shown that algebra can be developed from postulates, and may come to understand how rules can be unified and made more significant.

In order to determine the feasibility of a structural approach to geometry, Luchins and Luchins (43) introduced the concept of area to a VIB class by using this intuitive approach. In four forty-minute sessions, the pupils were able to discover how to find the areas of rectangles, parallelograms, triangles, and various types of trapezoids. They also taught the concept of area by the structural method to nine girls, ages five to nine, a high-school geometry class, and a college-freshman mathematics class and found that their technic of presentation consistently provided better understanding and assured more certain retention of formulas.

After carefully analyzing the logic involved in indirect proof in geometry, Lazar (42) discussed three methods of indirect proof and concluded that the method of inconsistency can be most readily rationalized and is most convincing psychologically. He included a lengthy bibliography.

Mossman (49) analyzed a number of short-cuts that are often taught in arithmetic and algebra and revealed several inherent sources of confusion. Hartung (28) and Hawkins (29, 30) presented selected annotated bibliographies in the area of secondary mathematics.

In discussing the planning of a program for the use of learning aids, Schorling (58) refuted numerous questionable procedures and then gave several basic ideas for improving the use of learning aids.

Jones (36) argued that multisensory aids must (a) give concrete embodiment to more abstract concepts, (b) must be applications that give added reality, and (c) must produce a better understanding of worthwhile mathematical principles. He then suggested a number of devices varying from an adjustable gangplank with parallelograms and triangles to devices that duplicate definitions of cissoids and trochoids.

Fehr (22) made several suggestions concerning the place of multisensory aids in the teacher-training program, and emphasized that if mathematical laboratory periods are provided, reality can be given to the subject without losing any of its abstract and theoretical aspects.

The "plus" phases that have been developed in the junior-high-school mathematics program in Washington, D. C. were reported by Schult (59). These include such activities as construction, dramatization, and collections. Sources of many materials were suggested.

Included in the report of the Committee on Multisensory Aids (18) were chapters concerned with drawing and design, demonstration and exhibit, models and devices, instruments and tools, materials for model construction, projection materials and equipment, and a historic discussion of models and devices. Each chapter included a bibliography.

The yearbook written by Kieley (38) was concerned with the history and the classroom use of surveying instruments. The historical information provided interesting enrichment material, and the numerous suggested applications are valuable for classroom use. A very extensive bibliography was provided.

Monthly descriptions and appraisals of learning aids were prepared by Syer and Johnson (65). These reports covered the latest booklets, charts, bulletin board displays, equipment, films, film strips, instruments, models, pictures, plans for construction, glass slides, sources of materials, and standardized tests.

Altho there have been numerous studies of the mathematics that students have retained, little attention has been paid to the mathematics which majors in this field have available sometime after study. Boeker (4) investigated the status of 131 beginning calculus students in respect to the pre-calculus mathematics which they had retained. She administered a test which included the fundamental ideas, basic concepts, and definitions from trigonometry, college algebra, and analytical geometry. In nine of the ten areas measured, a large percent of failures was found. Thirty percent of the students missed 74 percent or more of the 125 items in the test, and 92 percent of the students missed at least 30 percent of the items. Several specific suggestions were given for improving the basic work in pre-calculus courses, with chief emphasis on concept building.

To ascertain the relative merits of (a) posting test marks, (b) annotating test papers, and (c) supplying remedial work as a check on directed study, Weiden (69) conducted two consecutive twelve-week experiments. Posted, annotated, remedial, and control sections were equated according to mental ages, socio-economic status, and scores on the Breslich *Algebra Survey Test*. Thru the twelve weeks of each experiment, a brief test based on the work assigned for the directed study period was administered each day just before the close of the period to all sections except the control group. Percent marks were placed on the blackboard for posted sections, but no papers were returned. Annotated sections got each test back with annotations. Papers were returned to "remedial" groups, and special work was given to these sections during part of the following period. All sections were given other forms of the Breslich *Algebra Survey Test* at the end of eight and of twelve weeks. In the first experiment, the only statistically significant difference was between the annotated and control sections. In the second experiment, remedial sections had statistically significant gains over both the annotated and control groups. Questionnaires revealed that students liked the check tests, felt that they profited from them, and of the four methods used in the experiment the remedial method was preferred.

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CHAPTER V

Measurement and Evaluation in the Teaching of Mathematics and Science

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In the period covered by this review, a number of reports have appeared having as their purpose the interpretation of research in various areas of testing. The Forty-Fifth Yearbook of the National Society for the Study of Education discussed procedures for measuring understanding, with chapters devoted to the measurement of understanding in elementary-school mathematics (53), secondary-school mathematics (22), and science (23), and with material on health education (46) and technical education (56) having implications for those concerned with evaluation in the science fields. The Forty-Sixth Yearbook of the National Society for the Study of Education (39) was devoted entirely to science education and included chapters on the evaluation of outcomes of science education on the elementary level and on the secondary level. Crawford and Burnham (6) surveyed materials designed to measure specific achievement, differential aptitudes, and unitary traits, and discussed the basic principles of constructing and administering objective tests. Frandsen (14) and Fowler (13) summarized research on measurement of interests. Wrightstone (60) identified the frontiers of research in the measurement of aptitudes and achievement.

Increased Use of Objective Tests of Achievement

There is evidence of an increased recognition of the fact that objective examinations can be appropriately used in connection with problem- and essay-type tests. Stright (51) recommended the use of objective and semi-objective tests in college mathematics classes, and published a sample calculus test of the objective type. Zant (61) reported on the multiple-choice type examinations in college algebra, analytic geometry, and calculus developed by the United States Armed Forces Institute for judging the achievement of students in service. Ashford (2), reporting to the Division of Chemical Education of the American Chemical Society, described the work of the Committee on Examinations and Tests in preparing objective tests in inorganic chemistry, qualitative analysis, quantitative analysis, organic chemistry, physical chemistry, and biochemistry. He emphasized the Committee's belief that objective tests alone could not form an ideal testing program, while pointing out the unreliability of essay-type examinations.

Basing his argument on psychological grounds, Krout (30) indicated the need for three-level achievement testing. He recommended the use of forms of controlled word association to measure student development on

the perception-cognition level; multiple-choice or matching technics to measure development on the level of concept-formation, judgment, and reasoning; and essay-type tests to measure the formation of attitudes conducive to action in appropriate situations. Crawford and Burnham (6) pointed out that subjective appraisals of achievement together with the Carnegie Foundation's *Graduate Record Examination* yielded a better index of promise for advanced work than either predictor alone, and stated their belief that scholastic evaluation usually is most valid when both subjective and objective methods of appraisal are used.

Effects of Cooperation in the Preparation of Objective Achievement Tests

While cooperation in the preparation of achievement tests is by no means a new development, the participation and interest of subjectmatter instructors seems to have increased, with a resulting salutary effect on classroom instruction. The development of tests for the United States Armed Forces Institute enlisted the participation of many subjectmatter specialists (2, 61). According to Ryans (47), the Navy achievement-testing program showed that achievement tests can contribute to the improvement of course instruction. Participation in the development of examination questions helped instructors to identify areas of student confusion. Study of item analyses helped them learn wherein their instruction or the course syllabus was inadequate. The program contributed valuable supervisory information by aiding in the discovery of the extent to which schools were accomplishing their instructional goals. It also gave a basis for recommending revisions of curriculums, methods, and policies.

Ashford (2) reported that those who helped in the preparation of the American Chemical Society tests considered themselves benefited by both the necessity for continuous re-examination of aims, objectives, and subjectmatter content, and by the exchange of views with fellow teachers. As many as seventy-three chemistry instructors in sixty-one institutions cooperated in the preparation of a single examination. The Committee on Examinations and Tests of the Division of Chemical Education, feeling that the development of objective tests can have a definite effect on the improvement of teaching, invited the participation of all teachers of college and university chemistry courses in its work. Diederich (8), describing the comprehensive examination system of the University of Chicago, stated that the cooperation of course instructors with the examiners made the teachers unusually conscious of the objectives of the courses, and thus contributed to better teaching.

How Achievement Tests May Influence Curriculum Changes

Objective tests of achievement have sometimes been criticized as tending to preserve the *status quo* in education. Peterson (42), on the other hand,

found justification for curriculum change in results obtained by the use of a carefully constructed objective test of achievement in physics and chemistry. Results of its administration in high-school chemistry classes, physics classes, and physical-science classes demonstrated the practicality of developing a one-year science course in which physics and chemistry are fused.

Ohlsen (41) found that the present mathematics curriculum of forty-three Iowa high schools was not effective in helping young people attain mastery of those mathematical concepts and skills accepted as essential for meeting satisfactorily the experiences of ordinary life. His conclusion was based on statistical studies of the responses of more than 2800 high-school students to test items designed to measure the skills and concepts defined by the Joint Commission of the Mathematical Association of America and the National Council of Teachers of Mathematics. The general proficiency index (percent knowing how to select the correct answer) was 48.2 percent; the indices for arithmetic, graphic representation, algebra, and informal geometry were respectively 57.8, 60.2, 29.2, and 49.8 percent. Analysis of items marked incorrectly indicated that the most common causes of error were (a) lack of understanding of the correct method of solving a problem, (b) confusion concerning related mathematical terms, (c) inability to select pertinent data, and (d) computational mistakes.

In a study concerned primarily with reading abilities in relation to success in mathematics courses, Eagle (9) found bases for recommending that the content of mathematics courses be selected and organized to emphasize methods of organizing and presenting data.

Measuring Problem-Solving Abilities

A trend in evaluation in science and mathematics education is increasing stress on outcomes other than memoriter learning of facts and principles. Diederich (8) pointed out that the University of Chicago examinations in the sciences never give more than 30 percent either of time or weight to recall of facts, but emphasize chiefly the use of facts in solving problems that have not been discussed in the courses. Smith (48) reported the relationship between the ability to reason about scientific facts, as measured by a particular test, general intelligence, and recall of scientific information. He found that scores on the reasoning test and scores on an informational test correlated to about the same extent with scores on a test of general intelligence ($r = .580$ and $.585$ respectively), and that scores on the reasoning test and scores on the informational test were more closely related ($r = .770$).

Spache (49) constructed an arithmetic-reasoning test designed to measure ability to (a) recognize or understand the facts given, (b) decide what facts must be found to solve a given problem, (c) choose the appropriate arithmetical computation, (d) estimate a probable answer, and (e) execute a solution. The test was administered to 158 pupils in the fifth and sixth

grades and is currently undergoing revision on the basis of item analysis and intercorrelations of the subsections. Study of the 27 percent of the respondents with the highest scores and of the 27 percent with the lowest scores showed that those in the low groups also had lower scores on a test of general ability, on experimental tests of reading and writing numbers, signs, and symbols, and of arithmetic vocabulary, and on a test of arithmetic fundamentals.

Lyda (32) recorded the words and actions of thirty-five pupils in Grades VII thru XI as they tried to solve out loud realistic verbal problems in arithmetic. An analysis of the records indicated that important causes of difficulty were inability to analyze a problem to find out what is required, what information is given, and how the data may be used; inability to outline a method of attacking a problem; a tendency to manipulate figures without understanding; inability to check the reasonableness of a solution; and computational difficulties. He also reported (33) that ability to solve realistic reasoning problems appeared to be positively related to general intelligence.

In measuring understanding and judgments in arithmetic, Sueltz (52) used objective materials, such as pieces of paper to be divided in half by lines, and circles whose areas were to be compared. He also prepared more than 400 multiple-choice test items, many of which were accompanied by sketches. Between 300 and 400 pupils in Grades IV to IX responded to the items. Groups of students were interviewed in order to identify the procedures they used in arriving at answers. The investigator found that formal computations seemed to be a stumbling block to the development of judgment; that the desire to compute glossed over the elements of understanding.

As a result of interviews with forty-four children four and five years old, Mott (38) reported that children of the age studied can readily master the names of numbers and reproduce them in any sequence; that about 92 percent of the children have concepts for the numbers one to ten; that about 72 percent recognize the first five ordinals and 64 percent can reproduce them, while 66 percent recognize and 20 percent can reproduce the first ten ordinals; and that the children can add and subtract readily when playing with blocks. Of the twenty-three children about to enter first grade, 90 percent counted by rote to ten, 82 percent to fifteen, 50 percent to twenty, and 22 percent to one hundred. Stotlar (50) held interviews of the same pattern with nineteen children four and five years old. She found no marked difference between counting by rote and counting objects; 70 percent of the group could count to ten or above both by rote and by concept. All the children were conscious that there were such things as written numbers.

In the science field, Oakes (40) asked for explanations of natural phenomena from thirty-five college faculty members, all of whom held at least

a master's degree in some field other than science. These adults exhibited very little in the way of a consciously reflective or logical procedure in attacking unfamiliar problems.

Measuring Abilities Involved in Generalizing

The ability to generalize was investigated by Ebert (10), who found a positive correlation with mathematical proficiency. He asked approximately 900 eighth-grade students: (a) to give an illustration of a mathematical relationship that was similar to several illustrations analyzed; (b) to write a statement in words of a general truth represented by several given illustrations of a mathematical relationship; and (c) to express in written form a specific illustration of a general truth in elementary mathematics that had been studied in verbal form. He found that the most difficult of the three tasks was the second.

Similarly, Alpern (1) found that to suggest procedures for testing hypotheses seemed more difficult for high-school science students than to select such procedures. The ability to suggest ways of testing hypotheses, as evidenced by 248 students, appeared to be related to the habit of delayed responses, altho this relationship could not be definitely established. The ability of 448 high-school science students to select procedures for testing hypotheses was not significantly related to chronological age, general intelligence, reading ability, sex, or the number of terms of high-school science study.

The ability to test hypotheses is one aspect of what is frequently called scientific method. Another aspect is the ability to formulate hypotheses in accord with the facts. Roody (45) devised a test, intended for use in high-school English classes, aimed at measuring progress toward realistic thinking. She invented a number of story plots, each with five endings. One of the endings contradicted the facts given; one was contrary to natural laws; two were possible; and one was exaggerated or morbid.

Testing the Ability to Apply Principles

The ability to apply principles was measured by Wise (59), who prepared a series of unit tests in physics which were administered at the close of units of study in seven Nebraska high schools. Each test of ability to apply principles in practical situations was accompanied by a test measuring recall of the principles and ability to perform related computations. Results on the applications-of-principles tests and on the tests of recall were related about equally to scores on general intelligence tests, but the relationship had no predictive value. Wise concluded that the traits associated with application of principles were not identical with those associated with recall and computation.

Thelen (54) also attempted to measure the ability to apply principles of physical science. He broke down this ability into several aspects; for

example, to recognize a new application of a known principle, to rate statements as useful in explaining events, and to predict results of action. His testing technic utilized film slides and synchronized recorded sound, and achieved more realistic test situations than was possible with pencil-and-paper tests where facility in the manipulation of verbal symbols is a factor masking the nonreading abilities to be measured. The new technic included these steps: the title of a problem was projected on a screen and stated by the narrator (on a record); a situation was depicted and described; possible responses were presented in pictures and statements; directions were given by the narrator, who paused to allow the respondents to indicate their responses on answer sheets. This study was exploratory, and the investigator did not attempt to draw conclusions concerning the ability to apply principles, altho he found some evidence of increasing maturity of thought (from fifth to tenth grade) related to learning experiences. He pointed out these advantages of the testing technic: (a) uniformity of administration; (b) high motivation of the respondents; (c) minimization of the verbal element with increased validity of testing nonverbal objectives; (d) the possibility of appraising some fairly sophisticated objectives at a low-grade level.

Another attempt to approximate actual situations was made by Hendricks (24) in connection with laboratory work in chemistry. He developed test items based on diagrams and computed their validity by the use of associated items from a laboratory performance test. His validity indices ranged from .29 to .50 for items designed to measure objectives such as these: (a) Can the student read a measuring device with the required precision? (b) Can he bring the proper pieces of apparatus together for doing an assigned laboratory task? (c) Does he anticipate the effect of the change in conditions upon the outcome of his experiment? (d) Can he correctly select apparatus for processing substances in terms of their differing heat constants?

Robertson (44) reported a type of chemistry examination designed, as he stated it, "to distinguish laboratory thinkers from cookbook slaves." Students were asked to write directions, suited to a person of their own experience, for performing a given laboratory task, such as the isolation of a pure compound from a specified mixture. The use of handbooks and textbooks, but not laboratory manuals and private notebooks, was permitted.

In his report on the Navy testing program, Ryans (47) stressed the need for careful attention to measuring the actual objectives of instruction. He pointed out that it was more important to differentiate between "can do" and "cannot do" than to distinguish between "knows how" and "does not know how," and stated that performance tests were developed to measure achievement on the operational level.

The Importance of Reading Skills

A comparison of reading scores with grades in chemistry and physics, made by Krathwohl (28) showed a clear relationship between the reading ability of college freshmen and success in lecture courses in chemistry and physics. Of those whose reading scores were in the lowest fourth of the 1118 students tested, 64 percent failed chemistry or physics, and only 7 percent made honor grades. Of those with reading scores in the highest fourth, 24 percent failed, and 45 percent made honors.

An extensive study of the relation of certain reading abilities to success in mathematics was reported by Eagle (9). He determined success in mathematics by averaging the arithmetic reasoning and arithmetic computation scores on the *Stanford Achievement Test* with semester marks in eighth- and ninth-grade mathematics courses, and identified the effects on success in mathematics of these factors: mental age, reading comprehension, reading speed, general reading vocabulary, mathematics vocabulary, ability to interpret graphs, and ability to interpret algebraic formulas. Standard tests were available for the first four factors; tests were especially prepared for the last three. After partialling out mental age, it was found the mathematics vocabulary, the ability to interpret graphs, and the ability to interpret formulas were the factors most closely related to success in mathematics. There was no evidence in this study that improvement in general reading comprehension or general vocabulary would increase proficiency in mathematics. With respect to success in plane geometry, however, Truesdale (58) found that predictions of a grade of A or B in geometry could be made for 25 percent of all students with ninth- to eleventh-grade reading ability and for 50 percent of all students with twelfth- or thirteenth-grade reading ability.

Diagnosis and Remedial Instruction

There is no sharp dividing line between achievement tests and diagnostic tests. Traxler (57) stated that very few of the available tests in secondary school mathematics have extensive diagnostic features, but pointed out that teachers can make rough diagnoses from responses to individual items.

Tilton (55) administered *Compass Survey Tests in Arithmetic* to 138 fourth-grade pupils, and selected thirty-eight pupils showing a year's retardation for a controlled experiment on the effects of small amounts of individualized instruction. Nineteen of the children were given the *Los Angeles Diagnostic Test* and four weekly twenty-minute periods of remedial instruction based on the results. Three weeks after the last period of instruction, the entire population of 138 fourth-graders took another form of the *Compass Survey Tests.* Those children who had had remedial instruction showed a retardation of only seven months as against the twelve months' retardation of the control group. Burton (3) also found that remedial instruction in arithmetic resulted in improved test scores. He worked with high-school juniors and seniors who scored below the fiftieth

percentile on the Schorling-Clark-Potter *100 Problems Test*, and found that the group of forty who accepted remedial instruction improved by 17 percentile points while the group who had no remedial instruction improved by only 3 percentile points. Mahin (34) administered the *Stanford Achievement Test* to 142 high-school students who were either in the senior class or seventeen years old, and found that ninety-four failed (scored below 78). After twelve weeks of remedial work, sixty-six of the ninety-four passed a retest. Error analysis indicated that percent and division problems were most likely to be done incorrectly.

Guiler (17, 19, 21) analyzed the responses of 936 ninth-grade pupils to the Christofferson-Rush-Guiler *Analytical Survey Test in Computational Arithmetic*, and found that many errors could be attributed to lack of understanding of correct procedure as well as to computational mistakes. On the part of the test dealing with fractions (19), weakness in addition was evidenced by 23.0 percent, in subtraction by 42.5 percent, in multiplication by 42.5 percent, and in division by 40.7 percent. On the part of the test dealing with decimals (17), weakness was manifested as follows: changing fractions to decimals, 60.7 percent; changing mixed numbers to decimals, 82.7 percent; addition, 33.0 percent; subtraction, 33.3 percent; multiplication, 6.6 percent; division, 83.9 percent. On the part of the test concerned with percents (21), difficulties were encountered by 51.6 percent of the pupils in finding a percent of a number, by 47.7 percent in finding what percent one number is of another, by 94 percent in finding a number when a percent of it is known, by 72.2 percent in finding the result of a percent increase or decrease, and by 88.2 percent in finding a percent of increase or decrease. The over-all picture was very similar when the same test was administered to 925 freshmen in Miami University (16, 18, 20). The college freshman did considerably poorer on the fractions (percents showing weakness ranged from 44 to 63), somewhat better on the decimal part (6 percent to 64 percent), and about the same as the ninth-grade students on the percent problems (50 percent to 88 percent).

Kinzer and Fawcett (26) reported on an arithmetic test given to students at Ohio State University who elect beginning chemistry, comprised of fifteen problems involving the reduction of fractions to their lowest terms, the conversion of fractions to decimals, finding the missing term in a proportion, the computation of a percent, a verbal problem involving ratio and proportion, and a problem involving exponents. Of the 1439 students tested in the fall of 1945, 534 had less than one-third of the problems correct. These students were given an opportunity to participate in remedial sessions ninety minutes in length, held twice weekly for three weeks. At the end of this time, those taking remedial work were retested. Their scores on the retest ranged from 8 to 92 percent with an arithmetic mean of 52 percent. The remedial work appeared to have a definitely beneficial effect on success in chemistry, for no student who received 85 percent or higher on the retest received less than a C in his quarter's work in chemistry.

Investigations of Interests and Beliefs

Morton (37) studied questions about aviation collected from 3262 children in Grades I thru VIII. Of nearly 22,000 questions, 6410 had mathematical connotations. These were used to ascertain appropriate grade placement of arithmetic topics. The outstanding interests in all grades were in size, quantity, and time, including speed. Money in relation to aviation was of interest in all grades except the first and third; direction, in the third, sixth, seventh, and eighth grades; position and instrument reading, in the sixth and seventh grades; and pressure, in the eighth grade.

From a comparison of the responses of ninth-grade students to statements on a written test of superstitions and to situations in which actions might be conditioned by superstitious beliefs, Zapf (62) concluded that a paper-and-pencil test could be considered an adequate measure of superstitious beliefs. The paper-and-pencil test was given to 1135 ninth-grade students, and the results were compared with other factors (63). Girls were found to be significantly more superstitious than boys, and children of low IQ more superstitious than those of high IQ. There was a slight but significant decrease in superstitiousness with increase in length of science study. More superstition was found among those of low economic level than among those who were comfortably situated economically. There was evidence that pupils who were superstitious were poorly adjusted to other pupils, and a correlation of .50 was found between superstition and suggestibility.

Ralya (43) administered a check list of 180 statements concerning human nature to 141 college seniors in a premedical curriculum. About 67 percent of the students accepted the statement that the average white man is born intellectually superior to the average man of other races, and about 33 percent accepted the statement that the average man is born intellectually superior to the average woman. In general, physical indices such as those accepted by the adherents of phrenology and palmistry were believed by between 18 and 48 percent of the students to reveal traits of personality and character. There was usually some difference between the beliefs of the forty students ranking lowest scholastically and the forty ranking highest; for example, 30 percent of the low group accepted a traditional statement of phrenology that only 8 percent of the high group accepted. However, there was no difference between the groups with respect to a statement based on astrology; 20 percent of each group accepted it.

Prognosis and Guidance

Kraft (27) reported the general satisfaction of algebra and geometry teachers in Cleveland with the procedure for selecting their pupils, in which scores on the *Iowa Algebra Aptitude* and the *Iowa Plane Geometry Aptitude* tests were used to classify pupils into "surely," "maybe," and "no" groups, and evidence such as previous success in school was used to move students from the "maybe" group to one of the other groups. When

students were permitted to take the courses on other bases such as parents' wishes, grades were poor. In one instance, eleven pupils took geometry despite low aptitude test scores; seven of them failed the course and four received a mark of D.

Davis and Henrick (7) found that the best single measure of several considered for predicting success in plane geometry courses was the *Stewart-Davis Test of Ability in Geometry*, and that a test on algebra fundamentals was almost as good. The two tests combined had a very high predictive value: combined scores and success as measured by teacher-made achievement tests and the *Orleans Achievement Test* correlated to the extent of .95. Marks in eighth-grade arithmetic had a lower predictive value ($r = .59$). Challman (5) administered a Navy test of twenty arithmetic items and a specially prepared algebra test of twenty problems to 107 high-school geometry students at the beginning and near the end of the school year. The gains in arithmetic and algebra while studying geometry were significant, and correlations between final achievement in geometry and the various test scores led to the conclusions that ability in the performance of arithmetic and algebraic processes was one factor associated with achievement in plane geometry. Truesdale (58) reported that marks of A or B in plane geometry could be predicted for 10 percent of all students with arithmetic-placement scores in Grades IX thru XI, and for 40 percent of the students with arithmetic-placement scores in Grades XII and XIII. Holzinger and Swineford (25) found that spatial and general deductive factors could be measured and had greater value for predicting achievement in plane geometry than a teacher-made test administered after ten weeks of instruction.

When Krathwohl (29) compared success in college algebra, analytical geometry, differential calculus, and integral calculus courses with scores on the *Iowa Mathematical Aptitude Test*, he found correlations of .61, .52, .59, and .45, respectively, and concluded that the aptitude test had definite predictive value even two years after it was administered.

Meyer (35) studied the college achievement of students whose marks in high-school chemistry had been higher than their marks in other high-school subjects. He found that their marks in college chemistry were consistent with their marks in other college subjects, and saw no justification for excusing students from college general chemistry because they had had high-school chemistry. On the other hand, a more extensive study reported by Garrett (15) described a method of selecting students for advanced standing in chemistry. For several years, all students at Ohio State University who registered for chemistry after having had high-school chemistry were given a test covering the general physical and chemical concepts, a test covering the first quarter's work in college chemistry, and a laboratory performance test. Scores on these tests, together with intelligence test scores, provided a basis for granting or withholding advanced standing. Study of the results of this procedure led to the replacement of the test on general

concepts and the laboratory test by a short test on arithmetic. About 1500 students take the tests each fall, and from 5 to 15 percent are allowed to proceed directly to the second quarter's work in chemistry. The marks of 365 of these students were compared with the marks received in the second quarter's course by 904 students who had been required, on the basis of the same selectors, to take the first quarter's work. Of those given advanced standing, 80 percent received marks of A or B and 1 percent failed; of those not given advanced standing 28 percent received A or B and 11 percent failed.

In forecasting achievement in pharmacy courses, Moore (36) studied the predictive value of scores on a pharmacy mathematics test, a pharmacy problem-solving test, science-survey tests, the *Iowa Chemistry Aptitude Test,* and percentile ranking in high-school classes. She found the best predictor to be a combination of the mathematics test, a science-survey test, and high-school rank.

Identification of Special Ability

An attempt to discover the personality traits associated with mathematical ability was made by Cattell (4), working with 123 adult males in the Army Specialized Training Program. Carefully controlled ratings on thirty-five personality trait clusters were correlated with measures of mathematical and verbal ability obtained from scores on the *Graduate Record Examination.* The correlation of personality traits with mathematical ability was much the same as their correlation with verbal ability. Highest positive correlations were found with clusters designated as intelligent, analytical, wise, mature, strong-willed, conscientious, intellectual, wide interests, smart, and assertive. Highest negative correlations were found with the following traits: changeable, frivolous, character neuroses, psychopathic, infantile, demanding, changeable, and characterless.

According to Long (31), the relationship between interests as measured by the *Strong Vocational Interest Blank* and scientific ability as measured by the *Zyve Scientific Aptitude Test* was not sufficiently marked to permit prediction of the Zyve score even from the rating on the technical mathematics scale of the Strong blank. However, the results indicated that the Zyve test measures some factor that separates those with interests in technical mathematics from those with technical nonmathematical interests.

Edgerton and Britt (11) reported on technical aspects of the fourth science talent search. Four discriminators were used to select the forty winners from the 2746 students who filed complete entry data; a scientific-aptitude examination, high-school record, teachers' recommendations, and the ratings of three judges on a science essay. Partial regression coefficients showed that the aptitude examination and the essay carried practically all the linear discrimination. The aptitude examination consisted of two parts. The first part contained fifty multiple-choice items, each with four possible responses. The items were designed to reflect the general

breadth of interest in various areas of science and the ability to deal effectively with scientific materials. The second part was a paragraph-reading test, in which questions on reading were asked which could be answered by inference or reasoning from the information in the paragraph. The intercorrelation of the parts averaged .58. The total scores were found to be independent of the amount of mathematics taken or the number of science courses in which the students had enrolled.

The activities of all contestants in the first two science-talent searches, held in 1942 and 1943, and of all contestants who received honors in the later searches, are being followed annually by means of a mail questionnaire. Edgerton, Britt, and Norman (12) recently reported a study of the responses of boys who took part in the first search to the first three annual questionnaires. The data indicated that the boys selected for honors actually tend to be superior to those not so selected in terms of the following objective criteria: majoring in science; extent of education; college grades; honorary societies; scholarships or fellowships; and choice of professional field. The investigators stated their belief that the evidence so far obtained indicates that the science-talent searches are effective in selecting youth of scientific talent.

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CHAPTER VI

Teacher Education in Science and Mathematics

R. WILL BURNETT and LILLIAN GRAGG

VERY little research on the problems of teacher education in science and mathematics is available for the period of this review. Preparation for the writing of this chapter included an exhaustive survey of the professional journals and published studies. Letters requesting information on research completed or underway were sent to every college and university in the United States that maintains a graduate school or department of education. The majority of these graduate schools responded, yet few investigations in teacher education were reported. Of the studies completed during this period, or now in process, fewer still could be classified as objective research. Many of the studies included rest more on assumptions than on empirical data.

Criteria Basic to Teacher-Education Programs

Palmer (9) traced trends in the education of science teachers with particular regard to natural resource utilization. Part of Palmer's report was based upon research done by David Turner who visited practically all the training centers for work in wildlife conservation in the United States and Canada. As a result of about 800 questionnaire responses obtained from workers representing twenty-nine categories of the conservation program, he found the areas of training generally believed to be essential for effective conservation activities. Palmer conjectured that this study revealed one important source of objectives for the education of science teachers.

Richardson (12) examined the literature and reviewed certain outstanding problems to be faced in the education of science teachers. Unfortunately he did not provide a bibliography of the references he indicated were reviewed as a basis of his observations. Among the teacher-education problems Richardson listed are the following: (a) Prospective science teachers appear to exhibit a lack of understanding of the social function of science. (b) They tend to think in terms of subjectmatter boundaries rather than in terms of functional areas. (c) They largely accept as a single goal the imparting of information. (d) Most teachers in preparation have a very limited conception of the function of the laboratory in the learning situation. (e) They lack knowledge of available teaching resources.

Burgess (4) reported the procedure followed in Cleveland to determine the college courses in science and science education needed by elementary teachers. A working committee utilized a questionnaire to determine the needs of elementary teachers for content and experience areas. Brandwein (2) reported the beginning stages of the building of a curriculum in Forest Hills High School, New York, for students anticipating four years

of science. This program was arranged from a functional point of view and was student-teacher planned. Chemistry, physics, biology, and other areas of science are utilized as required in order to solve the problems undertaken by the students. This experimental curriculum is reported in this section of the REVIEW as representative of trends in science teaching requiring modified programs of teacher preparation. Brandwein summarized as follows: "If the type of teaching which deals with problems of living is desirable, then we need wide and drastic changes in teacher training. Teachers who participate in a program focused on problems of living must know more subject matter, more of the behavior of adolescents, than those who concern themselves merely with subject matter."

Explorations similar to the foregoing have been conducted in regard to the preparation of mathematics teachers. The Commission on Post-War Plans created by the National Council of Teachers of Mathematics (8) issued its second report consisting essentially of theses concerning the preparation of mathematics teachers in Grades I to XII. Two of these basic concepts, from study of the literature, general policy statements, and the experience of the members of the commission, follow as examples of the general type of statements given in the report. (a) Courses in mathematical subjectmatter for the prospective mathematics teacher should be professionalized. (b) It is desirable that a mathematics teacher acquire a background of experience in practical fields where mathematics is used.

Status and Trends in Teacher Preparations

Maaske (7) analyzed the literature and reported trends concerning preservice education of teachers. The study included teachers of all fields. He concluded that orientation and survey courses in the sciences, as well as in other areas, are increasingly providing the general education base on which the subjectmatter specialization of the teacher is being built. In contrast with this trend, Crowell (5) described changes in science education at the State Teachers College at Trenton, New Jersey. As a result of opinion polls of both students and faculty, survey courses were modified and retained for elementary teachers and abandoned for those planning to teach academic subjects in high schools. For this latter group the survey type of course was replaced by separate subjects such as descriptive astronomy and geology. Other trends reported include increased first-hand experience for student teachers, and increased emphasis on laboratory and field work.

As a result of his study of the literature on the topic, Breslich (3) presented observations concerning the preparation of high-school mathematics teachers. Fawcett (6) pointed out trends in the education of mathematics teachers and discussed characteristics necessary for effective teaching and the nature of the preparation of mathematics teachers designed to result in such characteristics. Reeve and Howard (11) traced the trends and problems in teacher training in mathematics, particularly in student teach-

ing. The literature and the student-teaching programs in various schools were the sources of their observations.

Prall (10) analyzed state programs for the improvement of teacher education carried out by the Commission on Teacher Education of the American Council on Education. Programs are reported in broad outlines. As an example, West Virginia has a single basic curriculum for both elementary and secondary teachers that includes six hours of biological science (integrated course) and the same for the physical sciences. This single curriculum leaves forty-one hours for electives. The secondary-science teacher must complete courses in his two teaching fields within these forty-one hours.

Walter (13) established an experimental group of student science teachers at Teachers College, Columbia University, and made a thoro analysis of the results of the experimental program. Certain basic concepts, such as "Student teaching should afford contact with all the important phases of a teacher's activity (both in and out of school)," were tested. According to the conclusions of the investigator, all concepts tested were found to be sufficiently rewarding to merit a marked modification of the traditional program of student teaching.

In a study of the certification requirements of elementary-school teachers in sixteen states, Blyler (1) found the minimum number of semester hours of mathematics required was two, the maximum five, and the average 3.4 hours. The minimum of science required was two, the maximum twenty-one, and the average nine semester hours.

Problems Needing Investigation

It is disconcerting to find that so few studies related to the education of teachers of mathematics and science have appeared over the past few years. Studies are needed on the determination of objectives of teacher education. Curriculum patterns should be developed and experimentally checked for adequacy. Little is known of optimum patterns of general education as background for mathematics and science teachers, of optimum structuring of content courses to provide the breadth and understanding needed by prospective teachers within the rigorous time limitations imposed by four- and five-year programs. We do not know, as fully as we need to know, what sorts of professional education and instruction in science and mathematics curriculum and instruction are soundest.

Over the past decade many studies have been made of the judgments of graduates from teacher-preparation institutions regarding their training. The products of our institutions have presented rather consistent patterns of objections to certain aspects of their preparation, yet little has been done to evaluate the modified programs as they have developed. It is hoped that the next issue of the REVIEW, devoted to the natural sciences and mathematics, will report much richer sources of valid studies on significant issues in teacher preparation than are now available.

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